SECTION 1 INTRODUCTION

The State of Montana in consultation with the Confederated Salish and Kootenai Tribes, and the U.S. Department of the Interior - U.S. Fish and Wildlife Service, contracted with WestWater Consultants, Inc., River Design Group, Inc., Wildland Hydrology and Geum Environmental Consulting, Inc. to prepare the Restoration Plan (RP) for restoration activities associated with the Milltown Reservoir Sediments Operable Unit (MRSOU). The RP follows earlier efforts including the Phase I Draft Conceptual Restoration Plan (DCRP) (Water Consulting, Inc. and Wildland Hydrology, 2003; amended 2004). The Final Restoration Plan will be completed following final data collection, and receipt and acknowledgement of comments from the Trustees, a peer review panel, and the public. The RP documents the Phase 2 data collection, analysis, and conceptual restoration design for the Clark Fork River (CFR) and Blackfoot River (BFR) following the removal of Milltown Dam and a large portion of the contaminated sediments stored in Milltown reservoir. The RP incorporates recommendations and information included in the Environmental Protection Agency's (EPA) Record of Decision for removing Milltown Dam and the excavation of sediments.

The RP culminates the second phase in the restoration planning process. Previous and future phase tasks are outlined as follows.

Phase 1: The Phase I DCRP as amended in June, 2004. The DCRP was a broad scale planning document that provided restoration concepts, draft plan views, and elevation information. Although the level of detail in the document was adequate to provide the best possible cost estimate based on existing information at the time, the document was based on limited field data collection and contained only conceptual restoration design plans.

Phase 2: Phase 2 RP includes field data collection activities completed in late 2004. Data were collected to characterize existing channel conditions and reference (or most probable state) river corridor attributes on the CFR and BFR in both the MRSOU and on other reaches of the CFR and BFR. Data were used to establish design alternatives and evaluate the feasibility of proposed design alternatives. Field data included existing topography, aerial photography, channel and floodplain morphology surveys, sediment investigations, and a riparian vegetation assessment. Aerial photograph interpretation and review of historical documents complemented field activities. Recent and time series aerial photos were reviewed to evaluate channel alignments, valley-channel interactions, and the influence of human infrastructure on the landscape.

Phase 3: The Phase 3 Design Plans will refine the restoration plans based on additional data and analyses as discussed in the RP and public comment. Thereafter, final design plans will be developed and will be used for acquiring permits and for directing restoration plan implementation.

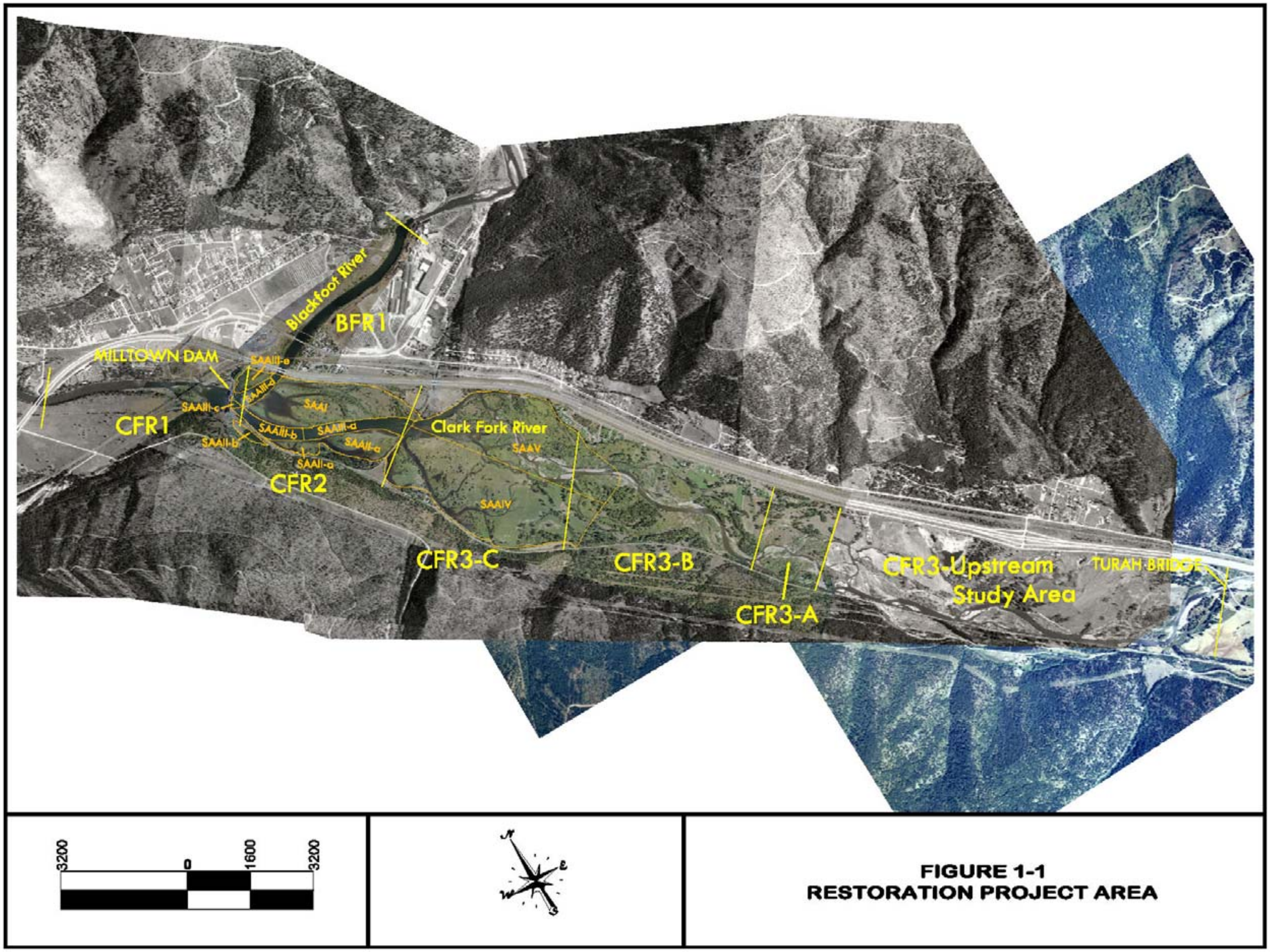


FIGURE 1-1
RESTORATION PROJECT AREA

1.1 PURPOSE AND SCOPE

The RP serves as the second stage planning document for orienting restoration planning for the CFR and BFR following the removal of Milltown Dam and the most contaminated sediments contained within Milltown reservoir. Information included in the RP culminates data collection, analysis, and modeling efforts completed in 2004 and 2005. Field data collection, aerial photograph interpretation, and review of historical documents served five primary purposes.

- To predict or at best, characterize, the likely historical conditions of the CFR and BFR in the vicinity of the confluence.
- To characterize the existing conditions of the CFR and BFR in the MRSOU and in upstream reaches.
- To propose the desired future morphological characteristics for restoring the CFR and BFR channels in the vicinity of Milltown reservoir based on data collected in reference reaches in other portions of the CFR and BFR watersheds. Restoration designs will also account for restoration project area constraints and limitations.
- To provide data necessary for modeling and evaluating flood frequency, channel stability and sediment transport capacity. Hydrologic and hydraulic modeling results are incorporated with empirical data to develop and evaluate channel restoration designs.
- To provide a complete topography of the restoration project area including bathymetry of existing deep water features that may be used for future design phases and analysis.

The intent of the RP is to present a summary of these efforts in addition to presenting restoration designs for the Clark Fork and Blackfoot rivers near the MRSOU. The RP has been submitted for peer review and peer review comments has been incorporated in the RP. This RP will be available to the public. Review and comment by others outside of the restoration design team to should maximize the potential for restoration project success and is a key component of the planning effort.

The extent of the proposed work will extend on the BFR from the confluence with the CFR, upstream to just below the Stimson Dam; and on the CFR from the Burlington Northern-Santa Fe (BNSF) railroad bridge below Milltown Dam, upstream to the extent of the reservoir and Duck Bridge hydrologic influence (Figure 1-1). The following products are intended to be completed during Phase 2.

- Develop a thorough understanding of historical and existing river processes responsible for forming the channel dimensions, planform, and profile. Example information that was collected and reviewed includes information pertaining to riparian conditions, hydrology, sediment transport, and anthropogenic land uses.
- Develop appropriate restoration recommendations based on historical, existing, and potential channel conditions while acknowledging the constraints that will be placed on the final restoration design. Example constraints include the location of contaminated sediments to be left in-place within the restoration project area, existing infrastructure, and budgetary limitations.

- Acknowledge and apply as appropriate a range of analysis techniques to thoroughly evaluate existing and potential river conditions. Appointed analytical techniques are based on the experience of a wide range of practitioners in the fields of fluvial geomorphology, hydrology, hydraulic engineering, and restoration ecology among others.
- Provide the collected information and proposed restoration designs for peer review and public critique to ultimately strengthen the restoration plan and provide the State with the best possible restoration project.

The State envisions the restoration of the CFR and BFR near Milltown Dam as a portion of a larger watershed scale effort being conducted in the CFR watershed. Restoration efforts on the CFR are largely in response to the waste from mining, milling and smelting operations in Butte and Anaconda. Existing river corridor have been injured by hazardous substances, including arsenic, cadmium, copper, lead and zinc. Addressing contaminated waste though various clean-up efforts has been underway since the 1980s. Removal of Milltown Dam and a portion of the contaminated sediment in the reservoir will result in the elimination of a large depository of contaminated materials from the CFR corridor.

1.2 PROJECT GOALS AND OBJECTIVES

The Trustees revised the goals and objectives presented in the Draft Conceptual Restoration Plan (DCRP) for the DRP per the peer reviewers recommendations. The review panel agreed with the conceptual goals and objectives but suggested more explicit wording that corresponded with our more detailed data and understanding of the site. The following goals and objectives were defined for the Draft Restoration Plan, April 2005. These goals and objectives will need to be refined further during the Phase 3 Design to reflect the monitoring that will be identified to measure the success of this project.

<u>Overall Project Goal</u>: Restore the confluence of the Blackfoot and Clark Fork Rivers to a naturally functioning, stable system. This goal can be achieved with the understanding that:

- Infrastructure, contaminated sediment repositories, private land and the geomorphic setting must be maintained;
- Erosion and migration of the river channels is part of a naturally functioning and stable river system. In the long-term, vegetation such as cottonwoods and willows is integral this restoration;
- For the short-term (15-25 years) after reconstruction, structures will be relied upon to provide stability until the vegetation is mature. To the extent possible, structures will be similar to those naturally occurring in less altered sections of the rivers.

<u>1. Goal</u>: Improve water quality by reducing the erosion of contaminated sediments.

- Rock, wood, and vegetation will be used to construct instream, streambank, and floodplain structures mimicking natural structures found in other, similar Montana rivers;

non-native biodegradable material may be used. (Measurement[1]: Material used is native or it is not, structure consistent with setting);

- Bank and in-stream structures installed to maintain channel and floodplain stability until vegetation has matured on the floodplain and streambank;
    - After the streambank and floodplain vegetation has matured (15 to 25 years) the channel and bank structures will have degraded allowing the river to migrate and develop channel(s) naturally across the floodplain (Measurement: Channel migration starts after vegetation has met ROD requirements and is structurally effective, monitor erosion rates, bed stability (aggradations/degradation) compared to reference reaches).

2. Goal: Provide channel and floodplains that will accommodate sediment transport and channel dynamics appropriate for the geomorphic setting.

- Design parameters for the channel to allow the 1.5 to 2.0 year flood frequency to access the floodplain. Design of the floodplain, terrace, and wetland features will accommodate all levels of flooding consistent with setting. Channel and meander geometry will remain consistent over time. (Measurement: sediment is transported through restored reaches without excess aggradations or scour, channel hydraulic geometry remains within design criteria.. Bank pins, cross-sections, and profiles will be monitored);
- Revegetation of the streambank and floodplain using a diverse community structure will be an integral part of the floodplain design (Measurement: ROD requirements met or exceeded)

3. Goal: Provide high quality habitat for all native fishes and other trouts, including continuous upstream and downstream migration while minimizing habitats that will promote undesirable fish species.

- Channel design will provide habitat features similar to reference conditions and consistent with stream type or geomorphic setting. Instream and bank structures will maintain habitat features until bank and floodplain vegetation matures allowing the geomorphic forces to create this habitat naturally. (Measurement: Goal 3 met thru achievement of Goals 1 and 2);
- To the extent practicable while restoring these large river systems, habitats favorable to northern pike or other potential undesirable species, e.g. shallow, slow, and warm water will be eliminated. (Measurement: northern pike spawning areas eliminated and not created)

4. Goal: Provide functional wetlands and riparian communities, where feasible. These communities will also provide improved riparian and wildlife habitat within the restored area.

- Wetland design will reference upstream and downstream wetland areas (Measurement: created wetlands with equal or higher ranking than exists in upstream or downstream wetland areas);

[1] Measurements are listed as potential guidelines for which goals and objectives will be measured. Examples of indices are listed as indices that could be used. Further refinement in the restoration planning and development of the monitoring and maintenance plan will discuss the indices that will be used.

- Use of a diverse vegetation plan will improve wetland quality (Measurement: created wetlands with equal or higher ranking than exists in upstream or downstream wetland areas);
- A majority of the floodplain should develop into wetlands, but is dependent on groundwater elevations after dam removal. (Measurement: measure wetland areas).
- Revegetation activities proposed increase floodplain vegetation diversity and provide for long-term floodplain and channel stability. (Measurement: ROD, Appendix G)

5. Goal: Improve visual and aesthetic values through natural channel design, revegetation and the use of native plants and materials.

- The design will create a riparian zone that has a diverse vegetative cover (Measurement: vegetation ROD requirements met);
- The river channel design will function similar to reference sections (Measurement: channel maintains designed stream type and dimensions, see goal #1);
- Revegetation, floodplain, and channel design will consider other proposed land uses (Measurement: integration of other restoration projects considered to the extent practicable without compromising these Goals and Objectives).

6. Goal: Provide safe recreational opportunities compatible with other restoration goals, such as channel and floodplain stability, sediment transport, and fish habitat.

- Establishing a naturally functioning system within the boundaries and limits present at the site are a priority; however, safety considerations will be evaluated with every aspect of the project. A totally safe river system cannot be built, rivers are inherently dangerous, and a system that is similar to other rivers in similar environments within Montana will be used to guide decision makers. (Measurement: Met goals 1 thru 5.)

1.3 PROJECT CONSTRAINTS AND LIMITATIONS

Restoring the CFR and BFR in the vicinity of Milltown Dam entails many inter-related parts that must come together to make a complete project for ecological restoration to be a success. The RP presents a restoration design that for it to be effective must be successfully transferred from a report to an on-the-ground project. With this under consideration, there are several constraints and limitations that were acknowledged during the design of the RP and that will have to be accounted for moving forward. Project constraints include the location and toxicity level of contaminated soils to be left in-place; existing infrastructure that restoration designs must accommodate; and budgetary limitations. More so than limiting the potential success of the project, the project constraints are issues that will be acknowledged and planned for during the project design.

The following terms and definitions are provided to clarify the concepts presented in the following sections. A restoration project area map is included in Figure 1-1.

Sediment Accumulation Areas (SAA): Designated areas where contaminated sediments are located. Five SAA's were identified by the EPA within the MRSOU, three are within the Remediation Project Area and two are located upstream of the remedial area.

Remediation Project Area: The area where remedial actions will occur. This area extends from Milltown Dam upstream to the bridges on the BFR and upstream on the CFR to Duck Bridge. Restoration actions will be implemented inside the Remediation Project Area, but many of these actions are limited by the Consent Decree outlining project responsibilities of the State and the Settling Defendants.

Restoration Project Area: The area where restoration actions will take place. The restoration proposed at this time is limited to the current upstream and downstream distances identified in the 2004 Amendment to the Draft Conceptual Restoration Plan (Water Consulting, Inc. and Wildland Hydrology, 2003). Work outside the current restoration project area may be completed in the future. The restoration project area is delineated in Section 1.5.2.

The DCRP proposed starting the CFR channel restoration just upstream from Turah Bridge and extending downstream to approximately Station 28+00 on the valley profile. Turah Bridge was selected because the bridge location was considered a stable point in the respect that it probably will not change location in the foreseeable future. The bridge and reach may change, but due to land ownership and access issues, the bridge location will likely remain constant. It is important for the upstream end of the restoration project to begin at a stable point to minimize the risk of channel change concerning channel location and gradient. Channel stability is necessary to minimize restoration project risk.

1.3.1 Sediments to be Left In-Place

High level toxicity sediments will be left in-place in SAA I along the Interstate 90 embankment and SAA IIIB in the existing CFR channel. The EPA allowed these sediments, approximately 350,000 cubic yards of contaminated material, to be left in-place. These areas will require stabilization in order to protect these sites from fluvial entrainment. The SAA IIIB sediments shall be located out of the 100-year floodplain. Removal of the SAA IIIB sediments is not required since they are not a source of contamination to the alluvial aquifer beneath Milltown and Bonner (USEPA, 2004). Removal of the SAA I sediments near the Interstate 90 embankment will not be required to facilitate construction of the bypass channel. Envirocon estimated a cost of $5 million to $8 million for the removal of these sediments. Considering the cost of material removal relative to the benefit that removal would provide, EPA deemed it acceptable to leave these sediments in place. The proposed channel and floodplain extent will be limited to a narrower belt width through the reach bracketed by the SAAIII-B sediments to the south, and the Interstate 90 embankment to the north.

The USEPA also determined that 4 million cubic yards of contaminated sediment in SAA II, IV, and V (see Figure 1-1) are not a threat to human health or the environment. The Trustees' goal is to minimize erosion in these areas through the use of intensive revegetation and bank stabilization structures.

1.3.2 Existing Infrastructure

There are seven existing bridges within the restoration project area. Five of the bridges are located on the BFR, including the two Interstate 90 bridges, the BNSF railroad bridge, the Highway 200 Bridge, and the decommissioned county bridge that is now limited to pedestrian traffic. On the CFR, two bridges are located downstream from Milltown Dam. The BNSF railroad bridge is immediately downstream from Milltown Dam, and the Interstate 90 bridge is located where the CFR enters a northerly heading downstream from the dam. Preliminary scour analyses have been completed on the BFR bridges by the Settling Defendants. Scour analyses will be refined during Remediation Design and completed for the BNSF railroad in the Phase 3 design. Other important infrastructure in the area includes the Interstate 90 highway embankment, secondary roads in the transportation corridor, and land development paralleling the river will need further consideration during final design phase. Individual land holdings will be evaluated relative to predicted flood elevations.

1.3.3 Recorded Archaeological Sites

There are five recorded archaeological sites in the vicinity of Milltown Reservoir. None of these sites are expected to be affected by Milltown restoration based on the RP. The State will continue to consult concerning these archaeological sites with the other Trustees and EPA during development of the RP and the implementation of the Restoration Plan

1.3.4 Land Ownership

Much of the restoration project area will occur on private land. Landowners have been contacted, but permission to implement many of the specific restoration actions has not been granted at this time.

1.3.5 Integration of Remediation and Restoration

The Consent Decree outlines specific responsibilities that the Trustees' restoration plan must complete within the Remediation Project Area. To address these responsibilities, the State will design the final channel and floodplain configuration, including dam removal depths, and the Settling Defendants will construct the design. The State will be responsible for the placement of channel structures, except on the BFR where grade control is the Settling Defendants' responsibility. The State will also revegetate the site and will be responsible for floodplain maintenance and channel stability until vegetation is established.

1.3.6 Restoration Activities Schedule

The timing of restoration actions within the Remedial Project Area will be important. The contractors completing the remediation work have a schedule that is dependent on their production rates and progress. If certain restoration actions are to be integrated with aspects of the remedial process, the restoration schedule must coincide with the RA schedule. An example of effective integration would be incorporating the excess excavation material from Reach CFR

3 into the backfill in CFR 2. The excess material generated in Reach CFR 3 will need to be available for use as backfill in when the SD's are ready to use it as backfill in Reach CFR 2..

1.4 HOW TO USE THE DOCUMENT

The RP is structured to 1) provide the reviewer with a thorough understanding of the concepts we followed in characterizing the CFR and BFR; 2) define the historical, existing, and potential river corridor conditions; and 3) develop restoration designs for reconstructing both rivers in the restoration project area.

This section includes descriptions of the systems that were employed in assessing the CFR and BFR; it defines time frames for ecological and hydrological restoration, explains the most probable state or reference condition concept and its application to river restoration, and provides an overview of the primary sections that comprise the remainder of the RP.

1.4.1 Technical Systems Used

The different technical systems used in our analysis were chosen because they are standard within each of their particular disciplines. Some were developed regionally, while others have been universally applied independent of geography. Systems may be delineated according to field and analytical techniques. Field techniques include methods for characterizing existing channel, aquatic habitat, and riparian conditions. Analytical techniques include remote sensing tools, and hydrologic, hydraulic, and sediment transport models.

Key field-based technical systems include the following methods.

- River morphology and channel classification concepts developed by Rosgen (1994; 1996) and other practitioners (Montgomery and Buffington, 1997; Montgomery and MacDonald, 2002). Presented methods are widely referred to in the literature and are applicable to the river systems evaluated. The classification concepts are used for describing assessed river reaches at a course level, and are primarily presented as a communication tool for conveying the general characteristics of specified stream reaches.
- The applied valley classification system focuses on the relationship of a stream system to its valley. Similar to the stream classification system, valley morphology classification is useful for conveying general information about stream valley characteristics including formative processes, dimensions, and how the valley morphology influences stream dynamics. Valley morphologies are classified according to guidelines presented in Rosgen (1996).
- Classification and Management of Montana's Riparian and Wetland Types (Hansen et al., 1995) is a vegetation-based ecological classification system centered on the dual concepts of ecological potential (habitat types) and disturbance-process-driven potential (community types). As a result, this approach provides a useful language for discussing desired future condition and understanding how restoring natural processes may influence vegetation communities on the landscape.

Key analytical technical systems used in this document include the following methods.

- Flood frequency analyses produced by the U.S. Geological Survey (USGS) (Parrett and Johnson, 2004) and updated by EMC^2 (2005) were evaluated for predicting the bankfull discharge and flood series for streamflow gaging stations on the CFR and BFR.

- Aerial photograph analyses were completed for the CFR and BFR in the restoration project area as well as in upstream reaches. Recent color aerial photographs were georeferenced using DIME® photogrammetric software and served as the base imagery for field maps, river planform analysis, and valley morphology assessment. Time series aerial photos of the CFR from Turah downstream to Milltown Dam were also georeferenced in DIME®. Historical channel alignments were digitized to assess past channel locations and patterns.

- River corridor topographic surveys were completed using a combination of ground survey, bathymetric survey, and photogrammetry. Data were merged to create a digital terrain model (DTM) of the restoration project area. Existing condition modeling was executed using both the DTM and the individual data components (e.g. cross-sections and channel profiles).

- Hydraulic models were developed to evaluate channel stability, incipient motion of sediment particles, and sediment transport properties. WinXSPro (West Consultants, 1998), HEC-RAS (U.S. Army Corps of Engineers, 2004), and Microsoft Excel (Microsoft, 2003) were the primary software programs used to develop the models. Bed resistance equations (Bathurst, 1997) and sediment transport equations (presented in Barry et al., 2004) were used to evaluate channel stability and sediment mobility in existing reaches and for the design channel dimensions.

- Reference reach data and regime equations describing potential channel conditions were evaluated to develop design channel dimensions. These regime equations based on large datasets included a range of variables including sediment, channel morphology, discharge, and vegetation condition characteristics (Wolman and Leopold, 1957; Millar, 2000; 2005). All hydrology and morphology data were stored and processed using RIVERMorph (RIVERMorph, 2005).

1.4.2 The Reference Reach Concept

Proposed restoration designs included in the RP have their basis in several methods including, analog (reference reach), empirical (regime and regional equations), and analytical (physical processes modeling) techniques. The reference reach concept is referred to throughout this document. Reference reaches were surveyed on both the CFR and BFR, and were located in reaches that exhibited conditions believed to represent the "best possible" river corridor conditions. Conditions exemplified by the channel's dimensions, pattern, and profile; the distribution and characteristics of sediment and sediment loading to the channel; and the riparian

condition were the primary factors in designating reference reaches. For example, a section of the CFR upstream from Milltown reservoir exhibits a relatively narrow width-to-depth ratio, well-vegetated banks, moderate pool frequency, and substantial pool depths. A non-reference reach, primarily referred to as an "existing" condition reach throughout the document, may be characterized by higher width-to-depth ratios, less efficient sediment transport suggested by mid-channel bar development, and less frequent and simplified pools. Channel braiding and excessive bank erosion were additional characteristics found in reaches believed to be functioning at a level below the most probable state conditions.

Ideally, a reference river reach is an integrated channel and floodplain system that is in dynamic equilibrium under the current hydrologic regime. A reference river reach may be a *hydraulic* reference reach where a channel is identified as in dynamic equilibrium under a current hydrologic regime, or it may be a *habitat* reference reach where diverse and complex habitat features are exhibited. We identified and surveyed several reference reaches in the field in order to fully characterize their morphological features. Those features provide a range of conditions that are used as a tool to help guide development of specific restoration proposals. For example, pool characteristics in a reference reach were surveyed and used to develop dimensionless coefficients that were then used for design purposes.

While identifying reference reaches at the present time is useful, evaluating historical conditions offers another opportunity for developing design channel dimensions. In this document, we used information gathered from the 1937 aerial photographs that captured the CFR from the Turah area downstream to Milltown Dam. Although substantial watershed-scale changes had occurred in the watershed dating to the 1850s, the channel pattern and recently abandoned channel locations provide some insights to historical channel alignments. Measuring the 1937 channel pattern and recently abandoned channel locations was useful for developing a range of channel planform dimensions that served as a basis for calculating design planform dimensions.

Reference plant communities were formulated by combining vegetative information from the CFR and BFR with regionally relevant plant community structure and composition information. Reference plant communities will guide much of the riparian and upland vegetative restoration that will coincide with river corridor reconstruction.

1.4.3 Summary of Sections

The RP is organized primarily as a summary document. Attached appendices present more detailed information pertaining to watershed hydrology, existing river corridor conditions, and sediment transport analyses, among other topics. Information from the individual appendices often overlaps (e.g. existing river corridor conditions and sediment transport analyses). Where overlaps do occur, summary information is provided and the reader may refer to the pertinent source appendix for a more detailed description of that item. This main summary document includes both original information and summary information taken from the appendices. The following summarizes the contents of the RP report and the attached appendices.

Section 1 is the introduction to the RP and also presents an introduction to the CFR and BFR with emphasis placed on the restoration project area.

Section 2 provides a framework for describing the historical, existing, and desired future conditions of the river corridor. Broad topical areas include a watershed overview, hydrology and flood-series analysis; valley, floodplain, and channel morphologies; vegetation conditions; wetland and off-channel habitats; fisheries and wildlife resources; and infrastructure effects in the restoration project area.

Section 3 provides proposed restoration strategies and techniques for reconstructing the CFR and BFR. The section identifies channel restoration strategies within the context of 1) the channels' interconnection with adjacent floodplain surfaces; 2) channel capacity and sediment transport continuity concepts; and 3) specific structures to maintain vertical and lateral channel stability. Section 3 also provides restoration strategies for wetland and vegetative recovery within the framework of reach-mapped hydrogeomorphic (HGM) cover types (Hauer et al. 2001). Additionally, strategies to move vegetative cover types to a desired future condition are presented.

Section 4 presents Restoration Plans for each project reach. Plans include design dimensions with supporting results from hydraulic and sediment transport modeling. Grade control and bank stabilization structures, revegetation prescriptions, Best Management Practices (BMPs), maintenance, monitoring and project sequencing are also presented. Several of these topics are in draft form at this phase of the project and will be furthered detailed in the *Phase 3 designs.*

Appendix A is the hydrology appendix. The hydrology appendix provides a detailed discussion of watershed hydrology including information on flood history, flood series, and bankfull discharge analysis techniques.

Appendix B is the geomorphic appendix. The geomorphic appendix discusses CFR and BFR river corridor conditions near Milltown Dam; information is based on an extensive field data collection effort and aerial photograph analyses. Supplemental information is incorporated from Appendix C, Appendix D, and Appendix F.

Appendix C is the preliminary channel stability assessment appendix. Included information pertains to channel geometry, channel hydraulics, critical shear stress and sediment transport modeling. Supplemental information is incorporated from Appendix B.

Appendix D reviews the valley and floodplain morphology analyses that were completed for the CFR and the BFR near Ovando, Montana. The Ovando Reach evaluation was completed to investigate channel, floodplain, energy gradient, and channel sediment relationships through a natural valley transition. The BFR in the Ovando Reach transitions from a moderately confined, meandering gravel bed river (C stream type), to a confined bedrock influenced channel (F stream type). The Ovando Reach was evaluated as a template condition for the CFR through Milltown reservoir where the river will transition from a meandering gravel bed channel with a connected floodplain, to a confined low sinuosity channel with no floodplain access following dam removal.

Appendix E presents the figures and aerial photographs that were used in the departure analysis. The departure analysis was completed to investigate the degree of channel variation between existing condition reaches and reference reaches, as well as CFR channel changes over time as indicated in the time trend aerial photograph interpretation.

Appendix F includes information on the historical, existing, and desired future fisheries and wildlife resources.

Appendix G introduces the vegetation and wetland resources analyses for the restoration project area. Information includes an analysis of existing conditions with emphasis placed on the description of native species, species' geographic locations, and the role of noxious weeds in shaping the vegetation community composition.

Appendix H covers the restoration plan strategies. Information includes the process that was followed in developing the design dimensions and plans. Supplemental information is incorporated from the preceding appendices.

Appendix I presents project plan view sheets including existing topography, 2004 aerial photographs, and draft design channel planform for the CFR and BFR.

Appendix J includes the draft design channel profiles for the CFR and BFR.

Appendix K includes the draft design typical cross-sections for the CFR and BFR.

Appendix L includes the typical grade control and bank stabilization structure details.

Appendix M includes the references cited.

Appendix N includes correspondence related to the peer review of this document.

1.5 OVERVIEW OF THE RESTORATION PROJECT AREA

The following section provides a brief overview on the effects of Milltown Dam and also includes a description of the river reaches that were surveyed during the Phase II data collection.

1.5.1 Direct and Indirect Effects of Milltown Dam

The MRSOU is located at the confluence of the CFR and BFR near Milltown in Missoula County, Montana. The reservoir is formed by Milltown Dam, a log and crib run-of-the-river dam completed in 1907 approximately 4 miles upstream of Missoula, Montana. The site is bracketed to the east and north by a major railroad, Interstate 90 with interchange, and local access roads. The southern and western boundary of the reservoir is confined by a second railroad grade and the Sapphire Mountains. Milltown Dam has substantially affected the physical, chemical, and biological processes that were historically maintained by the CFR and BFR in the restoration project area.

The 1908 flood of record filled the reservoir with sediments containing mining and milling wastes from upstream mining operations in Butte and Anaconda. The reservoir holds approximately 6.6 million cubic yards of sediments, about 3.0 million yards of which are heavily contaminated with metals, including 2,100 tons of arsenic, 13,100 tons of copper, 19,000 tons of zinc, 143,900 tons of iron, and 9,200 tons of manganese (USEPA, 2004). The depth of contaminated sediments rages from 1 ft to more than 20 ft near the dam. Water depth in the reservoir averages about 4 ft to 8 ft. Location of the dam has disconnected sediment transport processes through the target area. Although the reservoir is now considered to be in dynamic equilibrium regarding sediment transport (deposition and erosion in the reservoir are balanced (USEPA, 2004), sediment deposition upstream of the reservoir continues to influence channel stability on the CFR. The antiquated dam also does not meet safety (earthquake and flood) requirements (USEPA, 2004).

Metals and arsenic enriched sediment stored in the reservoir contaminates surface water and groundwater in and downstream from the reservoir. Geochemical conditions within the reservoir have contributed to the formation of a plume of arsenic-contaminated groundwater that has impacted the drinking water supply of the community of Milltown. Concentrations of copper, other metals and arsenic in the reservoir sediments represent a chronic and periodically, an acute hazard to aquatic life within the reservoir and immediately downstream, particularly when contaminated reservoir sediments are scoured during dam operations, elevated flood events, and periodic ice scour.

The location of the dam effectively terminates upstream migration for fluvial fish destined for both the CFR and BFR (Schmetterling, 2003). Although selective fish passage at the dam was initiated in the late 1990s to evaluate fish movement upstream of the reservoir, manual fish passage is costly and time-consuming. To address these issues, the EPA and the State of Montana have elected to pursue a Remediation plan, which calls for the removal of Milltown Dam and the most contaminated sediments stored behind the dam. The State of Montana and the other Trustees will pursue the restoration of the two rivers in conjunction with the Remedial Actions.

1.5.2 Reach Delineations

The CFR and BFR in the vicinity of the confluence were delineated into reaches based on the following criteria:

- Channel and valley morphologies.
- Extent of the direct and indirect influence of Milltown Dam and Duck Bridge on channel morphology and river processes.
- Stable geomorphic channel feature or geographic landmark.

The following reaches were delineated in the restoration project area as well as in other areas of the CFR and BFR watersheds for data collection and analysis purposes. The RP proposes actions in only the following areas, although some analyses were conducted in other reaches upstream and downstream from the Restoration Project Area as discussed in the next section. Figure 1.2 displays project reaches as well as specific study sites.

1.5.2.1 Restoration Project Area near Milltown Reservoir

- ***CFR1*** **–** CFR from the I-90 bridge (downstream from Milltown Dam), upstream to the confluence of the rivers. The CFR 1 channel length is approximately 5,500 ft.
- ***CFR2*** - CFR from the confluence upstream to the Duck Bridge grade. The CFR2 channel length is approximately 4,000 ft.
- ***CFR3*** **–** CFR from Duck Bridge upstream approximately 2 miles. The CFR3 includes three sub-reaches characterized by varied channel conditions (see Figure 1-1, map of the restoration project area). CFR3-A beginning at the upstream end of the reach and extending downstream approximately 2,000 ft, is dominated by a braided channel regime. CFR3-B is a single thread channel and was considered to exhibit most probable state (reference) conditions. CFR3-C is the lower end of the overall reach and is influenced by backwater deposition from Milltown Dam. The reach is dominated by a braided channel planform caused by reservoir deposition. The CFR3 channel length is approximately 7,000 ft.
- ***BFR1*** **–** BFR from the confluence with the CFR upstream to the Stimson diversion dam. The BFR1 channel length is approximately 5,700 ft.

1.5.2.2 Additional Reaches Included in the Analysis

- ***CFR Turah Gage*** - The U.S. Geological Survey (USGS) streamflow gaging station near the Turah Bridge (#12334550) was surveyed to estimate the bankfull discharge and channel dimensions for the reach. The survey reach extended upstream and downstream from the bridge.
- ***Missoula Gage*** **–** The CFR at the USGS streamflow gaging station above Missoula (#12340500). The reach extended from the Deer Mountain bridge downstream 1,300 ft to the top of a stable riffle. The reach was surveyed to estimate the bankfull discharge and channel dimensions through the gaging station.
- ***Bandmann Reach*** **–** CFR from the Interstate 90 bridge (downstream from Milltown Dam), downstream to the confluence of Marshall Creek. The reach was surveyed to characterize channel dimensions in the confined section of the CFR downstream from the confluence. The channel length of the Bandmann Reach is approximately 4,500 ft.
- ***Bonner Gage*** **–** The BFR at the USGS streamflow gaging station near Bonner (#12340000). The reach extended 2,900 ft from the top of a stable riffle upstream of the gaging station, downstream to Angelvine Park. The reach was surveyed to estimate the bankfull discharge and channel dimensions through the gaging station.
- ***Ovando Reach*** **–** The BFR near Ovando, Montana, was delineated into three reaches according to degree of channel confinement. Ovando Reach 1 is the upstream section characterized by an unconfined, meandering riffle-pool gravel bed channel morphology (C stream type). Ovando Reach 2 is a short section characterized by a moderately confined gravel bed riffle-pool channel (B stream type). Ovando Reach 3 is the

downstream section characterized by a confined riffle-pool gravel bed channel influenced by bedrock outcrops (F stream type). The Ovando Reach channel length totals approximately 14,400 ft.

1.5.3 Summary

Milltown Dam has profoundly affected the CFR and BFR in the remedial and restoration project area. The dam has influenced physical, chemical, and biological processes on both rivers and has modified these systems from historical conditions. The delineated project reaches were selected in order to document existing and reference reach conditions in the watershed. Collected data are used to characterize channel and floodplain morphologies as well as riparian vegetation conditions in the restoration project area. Detailed analyses completed for the CFR and BFR are included in the following report and appendices.

SECTION 2 HISTORICAL, EXISTING AND DESIRED CONDITIONS

The following section highlights the historical, existing, and desired future conditions for the CFR and BFR in the restoration project area. Included information is largely summarized from the respective report appendices that present more details for each topic. More comprehensive explanations for data collection methods, analyses, and results are included in Appendix B.

2.1 Cultural Resources and Land Uses Overview

The following sections present information on the cultural resources, historical and existing land uses in the river corridor, and additional background information on the restoration project area.

2.1.1 Cultural Resources

There are five recorded archaeological sites in the vicinity of Milltown Reservoir. None of these sites are expected to be affected by Milltown restoration based on the RP. The State will continue to consult concerning these archaeological sites with the other Trustees and EPA during development of the RP and the implementation of the Restoration Plan

Early European-American sites include the Military Road, railways, and homesteads. It is not anticipated that these resources will be affected by the restoration plan. Milltown Dam, the powerhouse, and related structures will be dismantled and removed. Milltown Dam and associated structures are considered to be an historic cultural resource and consequently, historical mitigation will occur as a part of remediation

2.1.2 Land Uses and River Reponses in the Floodplain Environment

Non-tribal land uses in the CFR watershed date to the mid-1800s when mining, agriculture, and grazing were pursued by early settlers (see Appendix D for a more complete description of historical watershed conditions and early land uses in the watershed). Gold strikes on Gold Creek, as well as placer and hydraulic mining in the headwaters of the CFR were underway by 1852 and well-established by the mid-1860s. Construction of the Military Road from 1860 to 1863, necessitated building river fords, bridges, and corduroying low-lying areas (Mullan, 1863). These activities required rock blasting, land clearing, and channel modifications on the CFR and BFR as well as side tributaries joining the CFR upstream of the confluence. By the time the Military Road was completed in 1863, herders were moving flocks of sheep numbering in the thousands through the CFR valley.

Construction of the Northern Pacific Railroad (NPR) and the CMSPR between 1883 and 1908 further constrained the river network. Bracketing the CFR, the railroads were

constructed to limit railroad length while also minimizing interactions with the channel. The NPR located on the northern and eastern side of the CFR had limited interactions with the CFR. Conversely, the CMSPR railroad bed was placed on the southern and western side of the channel alignment and interacted extensively with the CFR especially downstream of Turah. The railway narrowed the valley bottom and truncated channel segments.

Construction of Milltown Dam in 1906-1907 and increasing resource extraction in the watershed substantially modified the CFR and BFR. The dam disconnected river processes in the vicinity of the rivers' confluence. Sediment deposition behind the dam significantly accelerated during the 1908 flood of record when millions of cubic yards of mining and milling wastes were delivered to the reservoir. Estimated to be a 500-year return interval flood, the 1908 event when coupled with the historical human disturbances in the watershed, has been implicated as the primary cause of channel instability and braiding in the CFR study area.

Continued development in the CFR and BFR corridors has included the construction of Interstate 90 and Highway 200; floodplain development and associated flood control levees (e.g. Turah levee); mining; upland and riparian logging; and floodplain agricultural development.

Development has continued to influence the stability of the CFR near Milltown Dam, and to a lesser extent, the BFR. The CFR channel has been substantially altered by watershed development. The river system has generally responded to increased sediment loading, a narrower valley bottom, and increased stream energy by braiding. Channel braiding has also been exacerbated by the poor riparian condition that is increasingly represented by monoculture assemblages of noxious weeds that provide poor bank stability, cover, and displace more beneficial native species. As native plant species are replaced by noxious weeds with shallow rooting depths and limited woody debris recruitment potential, streambanks are less resistant to scour and therefore contribute more sediment to the channel network. Accelerated sediment delivery overwhelms the channel's ability to mobilize the sediment load and additional channel braiding occurs. This pattern of bank erosion, channel widening, and braid formation is common on the CFR from the Turah Bridge downstream to Milltown reservoir. Infrequent high magnitude floods and periodic ice floes further exacerbate channel instability, promoting a braided channel regime. Despite these processes, several reaches of the CFR have trended towards a single thread meandering channel pattern as riparian vegetation encroaches on the channel and stabilizes floodplain sediment.

The more confined channel morphology of the lower BFR is less affected by channel alterations in the watershed. The steeper gradient, larger bank materials, and greater stream power accounts for the more stable channel and more efficient sediment transport in the lower BFR. However, early log drives, construction of Highway 200, the flood of 1908, and the 1996 ice floe are believed to have scoured the channel. Stimson Dam, constructed after Milltown Dam, has caused additional backwater deposition and other localized channel changes.

In summary, non-tribal human land uses in the CFR and BFR watersheds date to the mid-1800s when mining operations were established in the upper CFR and tributary streams. Opening of the region with the completion of the Military Road in 1861 and the railroad in 1883, brought an increasing number of homesteaders into the area. Mining, logging, agriculture, and the modernization of the transportation corridor affected the historical character of the two rivers. The CFR, being more susceptible to river corridor disturbances than the BFR, has responded to extractive land use effects and periodic large magnitude floods by braiding.

2.2 GEOLOGY AND SOILS

The following section is taken from Milltown Reservoir Sediments Operable Unit of the Milltown Reservoir/CFR Superfund Site – Record of Decision, Part 2 Decision Summary (USEPA, 2004). Additional characterization of Milltown geology and soils may be found in NRCS (1995) and Alt (2001).

Milltown is located in an alluvial valley in the northern Rocky Mountain region of Montana. Valley width ranges from 0.75 miles to 1.5 miles upstream from the dam. Local relief varies from a low of approximately 3,250 ft above mean sea level in the valley to 6,813 ft at Bonner Mountain. This wide valley is underlain by Quaternary alluvial deposits and Precambrian meta-sediments. Valley alluvium consists of both laterally and vertically interbedded sand, gravel, and boulders with some clay lenses. This complex configuration of sediment deposits results from an apparent variation in the location of the CFR channel over geologic time. This material is exposed on both sides of the CFR and underlies recent reservoir sediments near the Milltown Dam. Well drillers' geologic logs indicate that the alluvial deposits generally thicken north of the reservoir and reach a depth of 155 ft within the southern boundaries of the Stimson Mill. Precambrian meta-sediments of the Belt Series underlie the valley alluvium. Argillite, quartzite, and limestone outcrop on Mount Sentinel, Bonner Mountain, and Sheep Mountain near Milltown. Several diabase sills and dikes intrude the metamorphosed sediments along the argillite-quartzite contact near the dam and on the slopes of Sheep Mountain.

2.3 HYDROLOGY AND FLOOD SERIES ANALYSIS

The following section provides an overview of the hydrology and flood series analysis that was completed during Phase II. The reader is referred to Appendix A for a more complete review of this topic.

2.3.1 Introduction

The watershed area upstream of Milltown Dam encompasses 5,984 square miles, with elevations ranging from 3,218 ft at the Milltown Dam powerhouse to over 8,000 ft at both the BFR and CFR watershed divides. The CFR watershed is located west of the Continental Divide with most of the headwater streams originating along the Continental

Divide. The BFR sub-watershed has relatively high mean annual precipitation ranging from 16 inches at the confluence with the CFR to 60 inches at the watershed divide (USDA Soil Conservation Service, 1990). The CFR sub-watershed has a lower mean annual precipitation ranging from 14 inches near Milltown Dam to 50 inches at the divide (USDA Soil Conservation Service, 1990). A majority of the precipitation in both watersheds occurs as snow that typically melts between April and June producing snowmelt runoff-dominated hydrographs.

2.3.2 Flood Series Analysis

This section presents updated flood magnitude and frequency data for the CFR and BFR USGS streamflow gaging stations for recurrence intervals of 2, 10, 25, 50, 100 and 500 years. Three gaging stations were analyzed including the CFR above Missoula (USGS Gage No. 12340500), CFR at Turah (USGS Gage No. 1233455), and BFR near Bonner (USGS Gage No. 12340000).

2.3.2.1 Flood Series Analysis

Flood magnitudes for selected recurrence intervals were determined from a flood frequency curve using the log-Pearson Type III distribution method (U.S. Water Resources Council, 1981; Parrett and Johnson, 2004). To account for the period 1998-2004, Environmental Management Consultants Corporation (EMC^2) conducted an additional analysis, extending the periods of record for the CFR at Turah and BFR near Bonner gaging stations through 2004. This analysis extended the periods of record for the Turah gage and the Bonner gage to 19 and 70 years, respectively (EMC^2, July 13, 2004 technical memorandum). The six additional years of data decreased the 100-year flood estimate for the CFR at Turah Bridge by 1,700 cfs, but did not substantially change the USGS analysis completed for the BFR near Bonner. Flood magnitudes for selected recurrence intervals for the CFR above Missoula were updated in 2005 by the USGS (C. Parrett, USGS, unpublished data). Flood series analysis results are summarized in Table 2-1.

Table 2-1. Log-Pearson Type III flood frequency analysis results.

USGS Station	Recurrence Interval (yrs)					
	Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
CFR at Turah Bridge	4,600	9,700	12,600	14,700	16,900	22,100
BFR near Bonner	8,670	14,600	17,300	19,200	21,000	24,900
CFR above Missoula	14,580	25,680	30,780	34,370	37,770	45,150

2.3.3 Channel Forming and Bankfull Discharge Analysis

A channel forming discharge and associated recurrence intervals for the CFR and BFR were calculated for the restoration project area. Although the precise definition of the channel-forming or dominant discharge varies (Wolman and Leopold, 1957; Knighton, 1984; Emmett and Wolman, 2001; Shields et al., 2003), the general concept of the role of

the bankfull discharge in channel maintenance is undisputed. The channel-forming or bankfull discharge is considered to be the maximum discharge that the channel can convey without overflowing onto the floodplain (Copeland et al. 2000). This discharge is considered to have morphological significance because it represents the threshold between the processes of channel formation and floodplain formation, and is associated with the discharge that dominates channel form and process. Dunne and Leopold (1978) associate the channel forming discharge with a momentary maximum flow, which, on average, has a recurrence interval of 1.5-1.8 years as determined using a flood frequency analysis. For the purposes of this discussion, the channel-forming discharge is considered to be morphological bankfull (Charlton et al., 1978; Hey and Thorne, 1986).

2.3.3.1 Bankfull Discharge Determination

Two approaches were used to determine bankfull discharge for the BFR and CFR upstream of Milltown Dam: 1) analysis of flood frequency using historical streamflow gaging records, and 2) field calibration of bankfull discharge at the respective USGS gaging stations. USGS gaging stations are located on the CFR at Turah (#12334550), on the CFR above Missoula (#12340500), and on the BFR near Bonner (#12340000).

Method 1: Return Interval Discharge
The first method assumed that the channel forming discharge would approximate a flood recurrence interval of approximately 1.5 years. This assumption is consistent with results from a detailed USGS study for western Montana that investigated the bankfull recurrence interval discharge for 41 gaged sites (Lawler, 2004). The study reported a median recurrence interval value of 1.5 years (range 1.0 to 4.4. years) for western Montana streams, which is similar to results reported from other studies (Dunne and Leopold, 1978; Moody and Odem, 1999; Castro and Jackson, 2001; and Cinotto, 2003). $Q_{1.5}$ results were derived from the updated log-Pearson Type III frequency analyses completed for the three gaging stations in the restoration project area (Table 2-2).

Table 2-2. Gage height (GH), dominant discharge (Q), and unit discharge expressed as cubic feet/second per square mile (CSM) results applying the return interval discharge method (RI=1.5 yrs).

USGS Station	GH (ft)	Q (cfs)	Drainage Area (mi^2)	CSM
CFR at Turah	5.02	3,004	3,641	0.83
BFR near Bonner	6.24	6,059	2,290	2.65
CFR above Missoula	6.53	9,892	5,999	1.78

Method 2: Field Calibration
The second method included field calibration of bankfull discharge at the USGS gaging stations (Table 2-3). Prior to field survey, discharge rating curves and hydraulic geometry relationship were developed from USGS 9-207 forms (summary of stream discharge notes) for a preliminary approximation of expected bankfull channel dimensions. At each gaging station, bankfull, water surface, thalweg and channel-distance data were surveyed. Data were processed in RIVERMorph v3.1 (RIVERMorph, 2005). Best-fit lines were plotted through the bankfull stage data collected in the field

and the gage height associated with bankfull discharge. The discharge for each gaging station was then plotted on the updated flood frequency curve to determine the recurrence interval for the associated bankfull discharge.

The discharge values for the gages at the BFR near Bonner and the CFR above Missoula are within 1.6 and 2.5 percent of the predicted values that were derived using the return interval method. Results for the CFR at Turah deviate by as much as 15 percent from the return interval method. Possible explanations for this include the relatively short period of record for the Turah gage; survey error associated with determining bankfull indicators due to observed channel instabilities associated with the Turah Bridge; and the flood of 1997 which effectively reset the hydraulic geometry relationships and rating curve for the Turah gaging station.

Table 2-3. Gage height (GH), dominant discharge (Q), and recurrence interval (RI) applying the field calibration method for the CFR at Turah, BFR near Bonner, and CFR above Missoula USGS gages.

USGS Station	GH (ft)	Q (cfs)	CSM	RI (yrs)
CFR at Turah	5.44	3,443	0.95	1.77
BFR near Bonner	6.21	6,156	2.69	1.54
CFR above Missoula	6.75	10,418	1.73	1.62

2.3.4 Hydrology and Flood Series Summary

Flood magnitudes for selected recurrence intervals were determined from a flood frequency curve using the log-Pearson Type III distribution method (U.S. Water Resources Council, 1981). Two approaches were used to determine bankfull discharge for the BFR and CFR upstream of Milltown Dam: analysis of flood frequency using historical streamflow gaging records, and field calibration of bankfull discharge at the USGS gaging stations.

The selected flood magnitudes are based on the results of the updated flood frequency analyses completed by EMC[2] and the USGS (Table 2-4). The field calibration results were derived from morphological bankfull features at the respective gaging stations and were therefore selected as the more accurate estimates of the channel-forming discharge. For the CFR at Turah Bridge, the two results were averaged. Values were rounded to the nearest 100 cfs for reporting purposes.

Table 2-4. Selected bankfull (Q_{bf}) and flood flow values (cfs) for the CFR at Turah, BFR near Bonner, and CFR above Missoula USGS gages.

USGS Station	Recurrence Interval (yrs)						
	Q_{bf}	Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
CFR at Turah	3,200	4,600	9,700	12,600	14,700	16,900	22,100
BFR near Bonner	6,200	8,670	14,600	17,300	19,200	21,000	24,900
CFR above Missoula	10,400	14,600	25,700	30,800	34,400	37,800	45,200

2.4 CHANNEL, FLOODPLAIN, AND VALLEY MORPHOLOGY

The following section provides an overview of the historical, existing, and desired future river corridor conditions in the restoration project area. Phase 2 field data collection and aerial photograph interpretation were used to analyze valley, floodplain and channel morphologies of the CFR and BFR throughout the restoration project area. The reader is referred to Appendix B for a more complete review of existing channel geomorphology, Appendix D for a review of historical and existing valley and floodplain morphology, and Appendix E for the aerial photograph time-trend analysis.

Channel and floodplain morphology at the CFR and BFR confluence was a topic of study during the Phase II data collection. Historical information and the existing river corridor conditions were evaluated in an attempt to define the historical, existing, and potential channel and floodplain morphologies in the study area. Early maps depicting the CFR upstream of the confluence offer conflicting interpretations of the channel planform morphology. While several maps from the late 1800s and early 1900s characterized the river with a multi-channel planform, other historical maps illustrated the river as a single meandering channel. Maps and aerial photographs completed in the early part of the 1900s are believed to depict a river already exhibiting the effects of 50 years of extractive land uses and development throughout the watershed. Therefore, it is debatable whether these historical maps accurately reflect the pre-European-American conditions of the river corridor.

Ideally, restoration action near Milltown Dam would attempt to restore the CFR and BFR to their historical condition. However, the restoration plan has to account for the existing conditions, probable trends in channel morphology, and restoration project area constraints. Ultimately, four questions must be addressed before selecting the best possible channel and floodplain morphology for restoration action.

1. What were the historical conditions prior to the inception of human-related disturbances that began in the mid-1800s?
2. What are the existing conditions, trends, and mechanisms for river and floodplain morphological changes over time and space?
3. What are the constraints and limitations that the restoration plan must consider?
4. What is the desired morphology of the channel and floodplain given the existing conditions and restoration project area constraints?

To address these questions, a comprehensive geomorphic analysis was completed to provide recommendations for channel and floodplain design criteria. Appendix B and D summarize the data collection and analysis effort, and provide the basis for the design criteria.

2.4.1 Overview of Valley Morphological Setting

Definitions for meandering and braided channel conditions are well documented. Meandering channels are considered to be sinuous single-thread channels, although straight channels (sinuosity <1.5) are also included in this category (Leopold and Wolman, 1957; Van den Berg, 1995; Millar, 2000). The term braided refers to wide and typically shallow channels that at low flows, generally have exposed, unvegetated bars and islands. As discharge nears the bankfull flow, the bars are submerged and reworked (Millar, 2000). These two conditions represent end points in a channel continuum that includes an intermediate condition referred to as anastomosing, anabranching, or wandering channels. Anastomosing, anabranching, wandering, and multi-thread channels are characterized by multiple channels separated by stable, vegetated islands that remain emergent at or near bankfull discharge (Nanson and Knighton, 1996; Millar, 2000; Tooth and Nanson, 2004). The wandering channel type is considered intermediate to meandering and braided channel types. The continuum of channels represents a trend of increasing flow energy.

In order to place meandering river systems into context, it is important to recognize the hierarchical approach to valley and river classification. Several stream and river classification schemes have been documented and published. Most of these classifications are not hieratical in geomorphic process and therefore do not associate a river to the landform in which it exists. The landform or valley morphology influences the natural tendencies of the river system. Rosgen (1996) has published a hierarchical system to classify rivers within valley morphology. This system was used to stratify data and perform analyses performed in the following sections.

2.4.2 Valley Type Classification

The following section highlights the valley types for the restoration project area. The valley type partially defines channel morphology and may be used as a tool in predicting the likely historical CFR channel planform.

2.4.2.1 CFR2 and CFR3 Valley Classification

Prior to development, the CFR floodplain upstream from Duck Bridge existed as a Type VIII valley (Rosgen, 1996). These valleys are associated with multiple terraces in broad valleys with moderate gradients. Holocene alluvial terraces and wide floodplains are the principal depositional features. Both terraces and floodplains are well-vegetated in undisturbed conditions. High glacial terraces of Pleistocene age also occur in these valley types. Fluvial systems dominating Type VIII valleys include, sinuous channels, with slightly entrenched, meandering patterns and riffle-pool bed morphology. A river in regime maintains its average channel dimensions without aggrading or degrading as it laterally migrates across the floodplain. In these systems, riparian vegetation condition is essential for bank stability, controlling sediment supply, and maintaining the average channel dimensions. Riparian vegetation conversion and river corridor disturbance may

cause the river to deviate from regime conditions. Channel incision or braiding may occur as the river responds to disturbances that increase or decrease bank stability, sediment loading, and discharge.

Downstream from Duck Bridge, the CFR valley was likely a Type VIII valley transitioning into a Type II valley at the confluence with the BFR. A Type II valley would have characterized the CFR from the confluence downstream through the BNSF railroad crossing prior to construction of Milltown Dam.

2.4.2.2 BFR1 Valley Classification

The BFR upstream from the confluence to beyond Stimson Dam is predominantly a Type II valley. Type II valleys are characterized by stable, gently sloping hillsides and a valley floor gradient of 4 percent or less. Sediment sources are generated through stream-borne alluvium and hillslope-derived colluvium. The vast majority of streams occurring in Type II valleys are moderately entrenched and relatively steep (2 to 4 percent slope) channels (B stream type). They are characterized as stable systems, confined by adjacent hillslopes with a typically low bedload sediment supply. Floodplain development is moderate with relatively narrow, sloping and well-vegetated floodprone areas. Sinuosity is usually low and the channel planform is structurally controlled. Bed morphology typically creates step-pool sequences or rapids (Rosgen, 1996).

2.4.2.3 CFR1 Valley Classification

Downstream from Milltown Dam and the BNSF railroad crossing to the I-90 bridge is a comparably unaltered Type IV valley. Similar to Type II valleys in their confinement and connectivity to adjacent hillslopes, Type IV valleys differ via the sinuosity and the level of entrenchment. Adjacent hillslopes are steeper and form a canyon or gorge-like valley bottom. Valley floor gradients are minor, usually less than 2 percent. Meander trains are usually incised and structurally controlled. Riffle-pool bed morphology exists and depending on consolidation of hillslope materials, sediment supply is moderate to high. Within these valleys, channels are typically confined and relatively flat (F stream type). Where lateral channel migration has created a floodplain, a meandering channel (C stream type) may evolve (Rosgen, 1996).

2.4.2.4 Summary and Discussion

This brief valley type overview outlines the valley conditions in the project reaches. Braided channel regimes are generally not associated with these valley types unless channel or floodplain disturbance increases sediment loading and bank instability. Disturbance may be related to both human and natural sources and recovery from a braided channel condition to a single thread channel is largely dependent on vegetation condition, bank integrity, and sediment supply.

Valley types and landforms normally associated with braided channels include:

- Debris-colluvial or alluvial fan landforms that are depositional in nature and valley gradients typically steeper than 2 percent.
- Glacial outwash plains or dunes, where soils are derived form glacial, alluvial, and eolian deposition processes.
- River deltas and tidal flats constructed of fine alluvial materials derived form riverine and estuarine depositional processes.
- Valleys controlled by tectonic movement or structural faults in the valley floor.
- Highly dynamic runoff patterns or hydrology.
- High sediment loads associated with landslides or unstable slopes.
- Steep valley floor slopes.
- Debris cones or alluvial fans.

None of these valley types or landforms occur in the CFR study area near Milltown Dam. Based on the presented valley types, a braided channel regime would not be expected in the CFR study area. Rather, the existing braided condition is more likely due to historical and contemporary land management.

2.4.3 Historical Floodplain Morphology

Before the transportation corridors were built within the CFR study reach near Milltown Dam, the natural extent of the floodplain was bounded on either side by high Pleistocene terraces and foothills of the Sapphire Mountains to the south, and the Garnet Mountains to the north. Floodplain widths upstream from the BFR ranged from approximately 1,600 ft to 3,000 ft with an average valley gradient of 0.0028. At the most confined point, a natural floodplain constriction existed. A Pleistocene terrace (near the Duck Bridge) formed the northern boundary and an opposing terrace on the southern boundary, reduced the floodplain width to about 1,600 ft. This constriction reduced the floodplain area by approximately 50 percent relative to upstream reaches. A naturally valley transition occurred from the Pleistocene terraces (station 93+00) downstream to Bandmann Flats. Through this reach, the CFR valley transitioned from a Type VIII valley, to a Type IV valley, to a Type II valley. This transition and narrowing of the valley bottom considerably influenced the channel planform.

Approaching the confluence of the BFR and Milltown Dam site (CFR2), the CFR was more structurally controlled by the narrowing valley. Valley gradients were generally steeper and glacial terraces and bedrock outcrops confined the floodplain width to approximately 800 ft through the dam area (1905 survey of pre-dam conditions). Downstream from the BNSF railroad bridge downstream from Milltown Dam, the floodprone width decreased to less than 450 ft.

2.4.4 Historical Channel Morphology

The historical channel morphology of the CFR through the restoration project area was studied using three methods. The methods included time series aerial photograph analysis of the channel planform and floodplain morphology; channel planform empirical equations; and comparison of the CFR-BFR confluence to other river confluences in northwestern Montana. These topics are discussed in more detail in Appendix D.

2.4.4.1 Time Series Aerial Photograph Analysis

An historical planform geometry analysis was completed for the CFR study area. The upstream and downstream boundaries of the analysis area were Turah Bridge and the upstream-most influence of the reservoir varial zone, respectively. Six aerial photograph series were reviewed including 1937, 1956, 1966, 2000, 2003, and 2004 (see Appendix E for aerial photographs). However, only four time series covered the entire analysis area: 1937, 1956, 1966, and 2000. Channel and floodplain morphology in this reach were compared to an upstream section of CFR near Clinton. References were also made relative to the Ovando Reach on the BFR.

Since only a small percentage of the active planform captured in the 1937 aerial photograph displayed measurable, single thread meanders, a traditional meander geometry analysis (Langbein and Leopold, 1966) was deemed unfeasible. As a result, conventional indices such as meander wavelength and meander radius of curvature were not practical as assessment tools for the majority of the reach due to the limited length of single thread channel sections. However, historical interpretation of meander belt width and channel sinuosity was possible. In addition, a limited comparison of meander geometry reference conditions was viable using the 2004 reference reach, the same reach in 1937, historical meander scrolls, and the Clinton reach.

The CFR channel planform was defined largely by the valley bottom width and the influence of constricting infrastructure. As stated previously, the CFR floodplain was historically confined by the Sapphire Mountains to the south and the Garnet Mountains to the north. The expansive floodplain provided the river with a wide expanse to laterally migrate. Well-vegetated banks most likely maintained bank stability and controlled sediment delivery to the channel. Construction of the railroad grades paralleling the river constricted the valley bottom width and reduced the active floodplain width. The infrastructure's influence on the channel pattern is notable in the consistent pattern of channel narrowing followed by braiding as the river responded to the artificial floodplain confinement.

The historical channel meander belt width and sinuosity exhibited a range of values based on floodplain confinement. Measurements recorded from the 1937 channel alignment as well as relict channels that appeared in the 1937 photo, suggest the channel planform dimensions were defined by a range of values. The lowest belt width values occurred where the transportation corridors encroached on the system, resulting in localized channel incision and minimal meander belt width. Maximum belt width values

corresponded to extensive braided reaches that occurred in unconfined floodplain sections. However, lower channel sinuosity was also recorded in these reaches as channel widths increased. In these reaches, lateral barriers were absent and the system had increased opportunity to widen its belt width. The repeating pattern of a narrow belt width followed by a reach with a wide belt width, corresponded to a confined reach with excess sediment transport capacity followed immediately by an unconfined depositional reach. The unconfined depositional reaches experienced braiding as the channel was not capable of mobilizing the sediment load contributed from the upstream confined degrading reaches. The BFR in the Ovando Reach contrasts with this degradation-aggradation pattern. The BFR in the Ovando Reach is a similar moderately confined gravel bed river. However, the BFR in the focus area was not been subject to extensive channel modifications. The relatively stable meandering channel has denser bank vegetation, greater sediment transport continuity, and a more consistent planform as a result.

A temporal pattern of channel planform conditions was also identified during the time series air photo analysis. It was determined that the river exhibited a temporal cycle related to large scale flood events. The channel typically widened and braided following large flood events. Between flood events, the channel narrowed as riparian vegetation colonized disturbed areas and floodplain deposits. This pattern was exemplified in many portions of the CFR. Through time, the CFR3-B reference reach has exhibited the greatest resistance to channel braiding. The upstream portion of the CFR3-B reference reach has remained relatively unchanged through the past nearly 70 years. Reasons for this could be the stabilizing effects of mature vegetation, a resistant terrace reinforced by the rail road grade, or a more expansive floodplain relative to other reaches.

In contrast to the dominant channel trend in CFR3-B, CFR3-A has remained extensively braided over time. Although the main channel and secondary channels have shifted and rerouted, the general braided planform has not changed. A consistent supply of sediment delivered from upstream reaches and also scoured from the channel adjacent to the highway embankment and railroad grade encroachments, maintains the braided planform. Accelerated sediment delivery is expected to continue as a headcut advances upstream.

2.4.4.2 Regime Equations

The potential historical channel planform were evaluated by applying meandering-braiding channel threshold regime equations. The meandering-braiding channel threshold has been a topic of interest for nearly fifty years dating to work done by Leopold and Wolman (1957) and Lane (1957). More recent work by Van den Berg (1995), Nanson and Knighton (1996), Millar (2000; 2005), and Tooth and Nanson (2004) expand model complexity in attempting to identify the variables that most accurately differentiate among straight, meandering, braided, and wandering channel planforms. We applied several of these equations in an attempt to address the question of historical channel planform for the CFR (see Appendix H for a complete discussion of this topic).

Regime equations offer another tool in predicting channel planform. Three models were used for predicting channel planform based on channel and valley slope, median particle size, bank angle, and vegetation condition. The regime equations provide a simplified means for evaluating channel planform. The variables in the models are generally surrogates for more complex processes. For example, bank angle in Millar's equation is an indicator of bank strength that could be related to bed material size and composition, and vegetation condition. Although these surrogate indicators make the models simpler, they also make the models more rigid. For instance, differences in bank and bed material particle sizes is not accounted for in Millar's equation, an issue that could be critical for evaluating bank stability and scour potential. Although evaluating more regime equation models would be one approach to further investigating the issue of historical channel planform on the CFR, the regime equations should be used as one of many tools in evaluating historical, existing, and potential channel conditions.

For the completed regime equations, the models predicted either a straight (Leopold and Wolman method) or meandering channel (Millar) planform for the CFR upstream from Milltown reservoir.

2.4.4.3 Comparison of the CFR-BFR Confluence to Other Similar Confluences in Western Montana

River confluences are generally complex, with many fluvial and hydraulic processes occurring during different seasons and flood events. An analysis of five western Montana river confluences that are similar to the CFR study area was completed to evaluate the frequency of channel braiding associated with regional river confluences. The confluences studied include the following rivers.

- The CFR/Rock Creek confluence near Clinton, Montana.
- The CFR/Flathead River confluence near Paradise, Montana.
- The CFR/Bitterroot confluence near Missoula, Montana.
- The BFR/North Fork BFR confluence near Ovando, Montana.
- The North Fork Flathead River/Middle Fork Flathead River confluence near Columbia Falls, Montana.

While this was not a detailed analysis, basic valley type, valley gradient and stream type summaries were conducted to determine the geomorphic similarity to the study area. The analysis was not intended to provide a definitive answer to the question of whether the CFR/BFR river confluence was historically braided, but simply to determine if the meandering form was common given current level of watershed development. The river confluence data are summarized in Appendix D, Table D-1.

Four of the five river confluences were characterized by single thread channels through the respective confluence areas. The only river confluence that exhibited braiding was the CFR/Bitterroot River confluence. However, at the Bitterroot River confluence, the CFR is heavily modified as it flows through the city of Missoula. At the confluence, the

CFR shows an anabranching to braided morphology, similar to the heavily impacted reaches of the CFR in the restoration project area.

Our preliminary analysis of river confluences in western Montana suggests that meandering channels are more common than braided regimes upstream from river confluences in the region. The results suggest that similar regional meandering river systems converge and remain stable over time. If the issue of braided versus meandering channel regime continues to be debated through peer review and public comments, a more exhaustive analysis of this topic will be conducted for the final project phase.

2.4.5 Existing Channel and Floodplain Conditions

A detailed geomorphic investigation of the CFR and BFR was completed in 2004. The primary goal of the investigation was to refine and validate the conceptual restoration design presented in the DCRP (Water Consulting, Inc. and Wildland Hydrology, 2003). The following sections summarize the field data collection and analysis effort (see Appendix B for a more complete discussion of this topic).

2.4.5.1 Reach Delineations

Geomorphic investigations were completed on the CFR from Turah Bridge near Turah, MT downstream to the Duck Bridge. This section of the CFR, referred to as the CFR study reach near Milltown Dam, was delineated into the three sub-reaches based on morphological characteristics of the existing channel. CFR3-A extended approximately 2,000 ft and was 2 miles downstream from Turah Bridge. CFR3-A was characterized by a primarily braided, multiple channel regime. CFR3-B extended from the lower end of CFR-3A downstream approximately 5,500 ft and was characterized by a primarily meandering channel plan form. CFR3-C included a braided channel regime extending from the end of CFR3-B downstream approximately 5,250 ft to Duck Bridge. Two additional CFR reaches, CFR2 and CFR1, were delineated. CFR2 is located downstream of Duck Bridge and is within the Milltown remedial action work area. CFR1 extends from the confluence with the BFR downstream to the Interstate 90 crossing of the CFR. In addition, the CFR was studied downstream from the I-90 bridges to the USGS streamflow gage in East Missoula.

To characterize potential reference conditions of the CFR downstream of Milltown Dam, an additional site was selected in the vicinity of Bandmann Flats near the Marshall Creek confluence with the CFR. The reach extended from the Interstate 90 bridge downstream to Deer Mountain Bridge. The final survey reach extended from Deer Mountain Bridge down through the USGS streamflow gaging station in East Missoula.

Geomorphic investigations were also completed on the BFR at the USGS streamflow gaging station located near Bonner and at three additional sites in the upper watershed near Ovando. The first study site was located 6.4 miles northeast of Bonner at the USGS streamflow gaging station, in the vicinity of the Angelvine fishing access. The survey included 2,900 ft of the BFR. Geomorphic surveys near Ovando encompassed

three reference reaches and included 2.6 miles of the BFR (see Appendix E for vicinity maps).

2.4.5.2 Data Collection Plan

Prior to field survey, a Level 1 coarse screen analysis was completed to stratify the restoration project area into discrete channel reaches based on several criteria including: 1) dominant landform and valley type, 2) existing and predicted channel state and condition class, 3) existing and potential riparian community composition, and 4) the upstream extents of the direct and indirect effects of Milltown Dam (Table 2-5).

Table 2-5. Level 1 coarse screen analysis parameters.

Parameter	Methods
Dominant landform and valley type	Rosgen, 1996 Montgomery and Buffington, 1993
Existing channel state and condition class	Rosgen, 1996 Montgomery and Buffington, 1993
Potential channel state and condition class	Rosgen, 1996 Montgomery and Buffington, 1993

Level 2 and 3 surveys were completed in the respective river reaches to characterize existing channel geomorphic form and degree of stability. Aerial photograph interpretation was completed using photos from the CFR. The time series analysis included photos from 1937, 1956, 1966, 2000, 2003 and 2004. Photos were georeferenced and merged to evaluate channel pattern changes and land development over time, as well as how land uses possibly influenced channel planform.

Existing channel conditions were evaluated in terms of equilibrium state, or degree of stability. A stable river reach was defined as one in which the average channel dimensions remain more or less constant over time amidst ongoing bed and bank erosion and deposition, meander cutoffs, and lateral migration (Millar, 2005). The following objectives were developed for the Level 2 and 3 analyses.

1. Develop a quantitative basis for comparing river reaches displaying similar morphologies, but which are in different conditions or geomorphic states.
2. Describe the channel's potential condition and contrast with the existing condition.
3. Determine the departure of the channel's existing condition relative to a reference baseline condition.
4. Measure field parameters that influence channel state including flow regime, stream size, sediment particle size distribution, sediment supply, channel stability, bank erodability, and direct channel disturbances.

5. Develop a basis for preparing channel restoration designs.

Table 2-6 summarizes the data collection parameters.

Table 2-6. Summary of Level 2 and 3 data collection methods.
Cross-sections (Harrelson et al., 1994)
Longitudinal profiles (Harrelson et al., 1994)
Planform Geometry (Langbein and Leopold, 1966; Thorne, 1997)
Substrate characterization (Wolman, 1954)
Riffle Stability Index (Kappeser, 1993)
Surface and subsurface particle distributions (Bunte and Abt, 2001)
Bank Erodibility Hazard Index (D. Rosgen, Wildland Hydrology, Unpublished Report).

2.4.5.3 Data Analysis

Topographic survey data were processed and analyzed in RIVERMorph (RIVERMorph, 2005). Cross-section data and longitudinal profile data were plotted and summary statistics generated. Sediment data including pebble counts, RSI data, and surface and sub-surface samples were also analyzed. Dimensionless ratios were computed for multiple variables.

Understanding the flow characteristics of the existing and design channels is important for anticipating likely channel responses to a range of environmental conditions. Two models were used to evaluate bed resistance and channel hydraulics. The U.S. Army Corps of Engineer's Hydrologic Engineering Center River Analysis System v 3.1.2 (USACE, 2004) was used to model existing channel conditions and validate bankfull discharge.

WinXSPRO (WEST Consultants, 1998) was also used to analyze cross-section data for geometric and hydraulic parameters. The theoretical background for analyzing channel cross-section data is derived from the basic continuity, momentum, and energy equations of fluid mechanics (WEST Consultants, 1998). The user's-supplied Manning's n coefficient method was used to evaluate channel capacity, flow velocity, and shear stress.

2.4.5.4 Discussion

The following discussion summarizes the existing channel and floodplain conditions information presented in Appendix B. The following information is organized according to study reach.

CFR Study Area

Reaches CFR3-A and CFR3-C are characterized by braided, multiple channel regimes. Sediment sources associated with eroding streambanks and bed instabilities were frequent with streambank erodability potential rating high to extreme. The increased availability of sediment and reduced sediment transport capacity have resulted in aggraded channel conditions and impaired aquatic habitat. The aerial photo series indicated that this condition has persisted in these sub-reaches since 1937 and that the system was likely sensitized by anthropogenic impacts and natural events well before this time period.

CFR3-B represents a potential reference or "best possible" state for the CFR, considering past anthropogenic impacts and natural perturbations in the watershed. Conditions exemplified by the channel's dimensions, pattern, and profile; the distribution and characteristics of sediment and sediment loading to the channel; and the riparian condition were the primary factors in designating CFR3-B as a potential reference reach. The reach exhibited a relatively narrow width-to-depth ratio, well-vegetated banks, moderate pool frequency, and substantial pool depths. Compared to the non-reference reaches which were characterized by higher width-to-depth ratios, less efficient sediment transport suggested by mid-channel bar development, and less frequent and less complex pools, CFR3-B was considered more stable and reflective of the potential channel morphology of CFR3.

Segments within CFR3-A and upstream to the Turah Bridge are presently aligned against the historical railroad grade located on the south side of the floodplain. In these sections, the river is channelized with elevated stream power, a function of the relatively deep channel thalweg, steep energy grade line, and increased mean channel velocity relative to upstream and downstream reaches. Elevated stream power is likely increasing the rate of fine and coarse sediment transport to the downstream braided channel regime in CFR3-A. The sediment transport competency is lower in CFR3-A relative to the upstream channelized sections and downstream single thread sections of the CFR in CFR3-B. Results of the incipient motion analysis indicate that up to the D_{60}-D_{65} (80 mm to 90 mm) of the bed material is mobilized during bankfull and greater discharges. The remaining size fractions, representing small cobble to small boulder size classes (90 mm to 256 mm) are deposited in the multiple channels.

Downstream in CFR3-B, the CFR transitioned to a meandering, single thread channel type. Bankfull riffle widths ranged from 138 ft to 206 ft and width-to-depth ratios from 37 to 77. Results of the incipient motion analysis indicated that the reach initiated movement of particles ranging from 95 mm to 105 mm. The effect of lower width-to-depth ratios increases the transport competency of the reach relative to upstream and downstream braided regimes. The efficient transport characteristics are likewise reflected in the stable bedforms, moderately deep pools, and bank stability.

As the CFR transitions to CFR3-C, the channel is again characterized by a braided, multiple thread regime. Valley slope is reduced from an average gradient of 0.0039 ft/ft in CFR3-A to 0.0030 ft/ft in CFR3-C. The channel materials are substantially finer and

the incipient motion results indicate decreased sediment transport competency, similar to CFR3-A.

In summary, the primary factors maintaining braided channel conditions within CFR3-A and CFR3-C include 1) abundant bedload supply; 2) high bank erodability reflecting the unstable channel conditions and altered riparian floristics; 3) historical flooding and variable discharge; and 4) backwater effects induced by Milltown Dam and potentially the Duck Bridge. Based on review of available data and information, it is likely that CFR3 was pre-disposed to braiding prior to 1937 and was particularly affected by the 1908 flood of record. Backwater effects imposed by Milltown Dam extended upstream to the lower end of CFR3-B. These effects resulted in decreased sediment transport capacity, sediment deposition, and accelerated lateral channel migration.

BFR Study Area

The reach assessments completed on the BFR near Ovando quantitatively described the geomorphic character of a system transitioning from an unconfined, alluvial valley to a confined, structurally controlled type. As the floodprone area and meander belt width were constricted in a down-valley direction, adjustments in channel morphological characteristics were observed, including channel width and depth, pool-to-pool spacing, and meander geometry relationships. In the three measured reaches, the channel geometry was balanced with the prevailing streamflow and sediment regime, with no net aggradation or degradation or significant reduction in sediment transport competency, despite relatively high rates of potential sediment loading compared to channels of similar type and morphology on the Clark Fork River (CFR3-B and CFR1 at Bandmann Flats).

The observations from the BFR near Ovando indicate that natural channels can transition from unconfined, alluvial valley types to confined types and maintain a stable, single thread channel planform. Applied in conjunction with other analytical and empirical analyses, the datasets developed from this assessment can be converted to dimensionless form and used to refine channel and floodplain design dimensions for the CFR3, CFR2, CFR1 and BFR1 project reaches.

The BFR near Bonner at the USGS gaging station represented a stable, functioning channel developed within a narrow, confined valley type. The reach classified as an entrenched F3 stream type and in locations where the floodplain was developed, a moderately entrenched B3 stream type predominated. The channel is incised into unconsolidated, heterogeneous and erodable glacial outwash terraces that provide a continual source of sediment to the channel where the river interacts with the terrace. This reach is similar in terms of valley form and channel type potential to BFR1. The dimensionless ratios generated from the reach assessment can be used to supplement companion analyses being conducted to develop channel design dimensions for BFR 1.

2.4.6 Desired Future Morphology and Constraints to the Restoration

Constraints within the CFR restoration project area upstream from the confluence may limit the belt width as well as the extent to which the river can migrate. Areas where contaminated sediments are to be left in-place along with budgetary constraints will ultimately guide the selection of a predominantly single thread, meandering river for CFR2 and CFR3. Constraints will also mandate that the restored river be relatively stable in the short-term (20 to 30 years) until the floodplain vegetation can maintain streambank and floodplain stability. RP objectives including maintaining channel stability and sediment transport; establishing native vegetation; improving aquatic habitat and water quality; and increasing recreational opportunities have the greatest opportunity for being achieved with a single thread channel planform.

In summary, the CFR and BFR cannot be restored to historical conditions due to past and ongoing disturbances. However, the analyses in Appendix B, Appendix D, and Appendix H indicate that a meandering, single thread planform for the CFR upstream from the confluence is the preferred planform. With consideration given to existing infrastructure, the lower CFR and BFR could be restored to near historical conditions with careful planning. Based on this analysis, a meandering C4 channel type, transitioning to a B3c channel type is proposed for the CFR upstream from the confluence. The B3c channel would continue through the BNSF bridge downstream from Milltown Dam, transitioning to an F3 channel type for CFR downstream from the BNSF bridge.

2.5 VEGETATION ASSESSMENT

The following section provides an overview of the vegetation analysis that was completed during Phase 2 (see Appendix G for a more complete review of this topic). Many factors influence existing vegetation patterns including geomorphic setting, water source, hydrodynamics, soils, vegetation, land use practices, and disturbance, for example. In addition, land use patterns and human-caused disturbance have caused significant shifts in vegetation communities, composition, and distribution.

2.5.1 Historical Vegetation Conditions

Because little information is available about vegetation prior to the construction of Milltown Dam, historical conditions are discussed based on observing riparian plant communities in adjacent reaches, combined with our knowledge of general disturbances affecting vegetation. Direct and indirect disturbances have altered ecological processes in the floodplains of both the Blackfoot and CFRs. Structures and activities that have altered ecological processes include: building of Milltown and Stimson dams, building of other infrastructure such as bridges, roads, and railroads, riparian grazing, development, and spread of invasive weeds. These activities have significantly altered the channel morphology as described in Section 2.4 which can affect the vegetation communities supported along the rivers.

In the absence of direct or indirect human disturbance, the historical channel and floodplain would have been narrower in CFR2, CFR3, BFR1, and BFR2 than they are currently due to the reservoir operation and other land uses. These lower reaches of the CFR and BFR likely supported forested riparian plant communities similar to those found in CFR3 in upstream reaches that continue to maintain gallery riparian forests. Vegetation communities likely consisted of non-climax cottonwood/red osier dogwood (*Populus trichocarpa/Cornus stolonifera*) communities interspersed with conifer dominated climax communities such as the Ponderosa pine/red osier dogwood (*Pinus ponderosa/Cornus stolonifera*) or Douglas fir/red osier dogwood (*Pseudotsuga menziesii/Cornus stolonifera*) habitat types (Hansen et al., 1995). Other historical plant communities likely consisted of willow (*Salix* spp.) and young black cottonwood community types on recently deposited sediments along the channel margins. Alder (*Alnus incana*) may have been dominant in isolated patches where cottonwood overstories died out and did not regenerate.

Historical upland communities that once characterized drier terrace vegetation have been significantly altered by logging, agricultural conversion, and land development. It is likely these areas once consisted of ponderosa pine forest and grassland community types.

2.5.2 Existing Vegetation Conditions

Existing vegetation patterns are influenced by hydrology, soils, and natural river disturbance processes as well as land use patterns and human-caused disturbances. As described above, disturbances have caused significant shifts in plant community composition. Existing vegetation is classified and described according to *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen et al. 1995). Plant communities are discussed in terms of their relationship to plant community succession and their response to natural and human-induced disturbance processes. The predominant plant communities occurring are described below by reach.

One of the most striking observations made while evaluating existing conditions on the floodplain was the significant weed infestations along streambanks and on floodplains. In the vicinity of Turah Bridge, reed canarygrass (*Phalaris arundinacea)* dominates the herbaceous layer under a stand of sandbar willow (Figure 2-1). Common tansy (*Tanacetum vulgare*) dominates a point bar, spotted knapweed (*Centaurea maculosa*) occupies slightly higher microsites, and canarygrass has colonized the immediate streambank. Because weeds are so significant, our revegetation strategies (Section 3) include several methods to limit weed infestation in restoration areas.

Figure 2-1. Existing vegetation conditions on the CFR floodplain in the vicinity of the Turah Bridge. Reed canarygrass dominates stream banks (left). Other invasive weed species including common tansy and spotted knapweed are other frequent noxious weeds (right).

<u>CFR1 Vegetation</u>
Reach CFR1 (downstream of Milltown Dam) has a very narrow fringe of vegetation along the channel. The plant community is predominantly willows and other riparian shrubs mixed with wetland herbaceous species. A mid-channel bar is dominated by sandbar willow (*Salix exigua*). A more detailed vegetation assessment should be completed as part of final design.

<u>CFR2 Vegetation</u>
Reach CFR2 consists of numerous vegetation community types. Vegetation communities consist of disturbed shrub communities dominated by black hawthorne (*Crataegus douglasii*) and alder. Some water birch (*Betula occidentalis*) is present, in addition to scattered willow. This reach includes the greatest area of emergent wetland vegetation due to the ponding effect of the dam. Ponderosa pine forest is present in this reach along the south bank in upland areas. Invasive plants species, including reed canarygrass, tansy, and spotted knapweed are abundant in the understory and have displaced many of the native understory plant species. We did not classify plant communities in Reach CFR2, nor did we develop a detailed plant species list, because our observations were made in February. A more detailed vegetation assessment should be completed as part of final design.

<u>CFR3 Vegetation</u>
Reach CFR3 consists of vegetation community types in various stages of succession. To the south of the river the vegetation is predominantly older age class cottonwoods with scattered pines along the channel. Wet areas in the floodplain are dominated by shrubs, predominantly black hawthorne in more disturbed areas, and willow species in less disturbed areas. The north side of the channel is predominantly a cottonwood forest with an understory dominated by red osier dogwood, or in more disturbed areas hawthorne, alder, or herbaceous vegetation.

BFR1 Vegetation

The BFR within Reach BFR1 supports a narrow fringe of vegetation along the channel. This vegetation is predominantly a sandbar willow habitat type. Backwater wetland areas also exist in this reach and are dominated by reed canary grass.

2.5.3 Desired Future Vegetation Conditions

The restoration objective is to restore the area to a condition similar to pre-dam construction, with naturally functioning riparian, upland and wetland components. Historical conditions in the restoration and reclamation areas were likely similar to those found along reaches upstream of the restoration project area in the absence of direct or indirect human disturbance.

The restoration project area was likely dominated by forested cover types such as black cottonwood/red osier dogwood and ponderosa pine/red osier dogwood. The black cottonwood community type (Hansen et al., 1995) is a reference plant community that represents the desired future condition for significant portions of the floodplain along the CFR. The distributions of land cover types and balanced channel dimension, pattern, and profile are also used to determine the desired future condition. Nearer the confluence of the CFR and BFR, plant communities may have also included shrub dominated cover types consisting of willow and other species.

Within this conceptual plan, a reference plant community approach is used as the basis for prescribing restoration actions aimed at revegetation. By observing plant communities growing along adjacent reaches with similar landforms and processes, plant communities are targeted in the restoration project area. While the desired future condition for vegetation can best be stated in terms of a suite of mature plant communities, restoration actions should focus on creating conditions that will support natural processes that can lead to development of these target plant communities over time. For example, willow and cottonwood communities require bare alluvial substrate with minimal competition from weeds to become established; therefore, restoration actions should at least partly focus on creating those conditions. As described in the Restoration Strategies section, below, natural processes should be used as a guide for establishing the range of plant communities desired within the restoration project area.

2.5.4 Vegetation Conditions Summary

The historical vegetation condition of the restoration project area is somewhat reflected by the existing riparian communities that are found in both the restoration project area as well as in upstream reaches. Historically, the riparian community was dominated by herbaceous species in the wettest portions of the floodplain. Willows and other hydrophytic shrubs (e.g. red osier dogwood) inhabited the channel margin and floodplain areas susceptible to flooding. Cottonwoods and water birch would have likewise paralleled the channel and contributed woody debris to the channel as the river migrated across its floodplain. Ponderosa pine and other more xeric species characterized drier terrace features confining the active floodplain.

Milltown reservoir, grazing, agriculture, floodplain development, deposition of sediments containing hazardous substances and the introduction of noxious weed species have altered the distribution and composition of plant communities on the CFR floodplain near Milltown Dam. Although Milltown reservoir has increased the wetted acreage upstream from the CFR and BFR confluence, noxious weeds have displaced native vegetation from large areas of the floodplain.

The desired future condition will promote the recovery of native vegetation in the restoration project area. The proposed revegetation plan (see Section 4.0) will accelerate native species recovery by treating noxious weeds and planting native species. Controlling noxious weeds to benefit the native vegetation community will be a long-term process that will require a diligent effort.

2.6 WETLANDS AND OFF-CHANNEL HABITATS

The following section provides an overview of the wetland resources and off-channel habitats analysis that was completed during Phase 2 (see Appendix G for a more complete review of this topic).

2.6.1 Historical Wetlands and Off-Channel Habitats

Specific data are not available concerning the historical extent of wetland and off-channel habitats along the restoration project area before Milltown Dam was constructed. Construction of the dam significantly altered the hydrology behind the dam, resulting in extensive ponding. Dam effects extend approximately 13,000 ft upstream from the dam. Prior to construction of the dam the wetland area was probably not as extensive as it is currently.

2.6.2 Existing Wetlands and Off-Channel Habitats

Existing wetlands are described using the Cowardin System, *Identification of Wetlands and Deepwater Habitats*, used by the U.S. Fish & Wildlife Service (USFWS) (Cowardin et al., 1979). The information in this section is based on field observations and is largely a summary of *Upper Clark Fork River Wetland Mitigation Process Step 3 – Detailed Analysis* by Walsh Environmental Scientists and Engineers, LLC. (2004).

2.6.2.1 CFR1 Wetlands

Very little wetland habitat exists in this reach. The channel is in a very narrow canyon with limited floodplain access. Plant communities are described in the existing vegetation section.

2.6.2.2 CFR2 Wetlands

This reach is located within the reservoir pool assessment area as defined in the *Upper Clark Fork River Wetland Mitigation Process Step 3 – Detailed Analysis* by Walsh Environmental Scientists and Engineers, LLC. (2004). This area consists of the reservoir pool and river channel and side channels upstream of the pool to Duck Bridge. Wetlands within this reach are primarily classified as Lacustrine (Cowardin, 1979) as a result of the pool formed by the presence of the Milltown Dam. Other wetlands are palustrine and consist predominantly of wet meadow and emergent wetland plant communities. Within these communities, wetter sites were more diverse, and slightly drier sites had lower native species diversity. Shrubs and trees include willow species, black cottonwood, water birch, mountain alder, western snowberry (*Symphoricarpos occidentalis*), Woods' rose, serviceberry (*Amelanchier alnifolia*) and gooseberry (*Ribes* spp.).

2.6.2.3 CFR3 Wetlands

Reaches CFR3 and upstream reaches are located within the braided river assessment area as defined in *Upper Clark Fork River Wetland Mitigation Process Step 3 – Detailed Analysis* by Walsh Environmental Scientists and Engineers, LLC (2004). The area is a palustrine system including emergent, scrub-shrub and aquatic bed classes. Open water is present in both small pools and large ponded areas. Wet meadows include patches of shrubs and trees. Reported species composition is similar to species composition in CFR2. A large wet meadow area is located to the west of the channel.

2.6.2.4 BFR1 Wetlands

Very little wetland habitat exists in this reach. Vegetation is confined to a relatively narrow corridor that parallels the channels due to developments (e.g. roadways, commercial centers and residential homes), or the physical characteristics of the landscape (e.g. steep side slopes, upland terrain). Some backwater areas and channel margins are dominated by sandbar willow and reed canarygrass.

2.6.3 Wetlands and Off-Channel Habitats Desired Future Conditions

The existing wetlands within the restoration area were likely expanded by the hydrologic influence created by Milltown Dam. However, side slope hydrology is also feeding wetlands along the south side of the project. The channel types proposed through the restoration areas (single channel compared with braided channel) do not typically support the type of extensive back-water wetlands and wet meadows currently present. Channel types proposed for restoration typically flood and create depositional areas which provide substrates where willows and cottonwoods communities become established. Outside of this area, channels typically support forested or shrub dominated riparian areas. Infrequently, large floods may cause the channel to avulse, moving to an entirely new location and leaving behind an abandoned channel that develops into a wetland complex. The lacustrine wetlands behind the reservoir will be lost during reclamation. Palustrine

wetlands along the channel that are fed by side slope hydrology will be maintained as much as possible. Wetland area will be maximized during final design and will include constructed depressions similar to natural oxbow features.

2.6.4 Wetlands and Off-Channel Habitats Summary

Existing wetlands and off-channel habitats are more plentiful now than they were historically due to the presence of Milltown Dam. The reservoir has expanded the distribution of wetlands and off-channel habitats. Dam removal and channel reconstruction will revert the system to a state more similar to the historical condition than to the existing river corridor condition. Floodplain diversity will be one focus area of the restoration design. Floodplain wetlands, off-channel habitats, and floodplain channels will be constructed to increase the distribution of micro-habitats on the floodplain. This effort will serve to provide a greater number of habitats for flora and fauna, as well as be an attempt to slow the domination of introduced noxious weeds that typically do best in simplified systems (e.g. consistent topographic surfaces).

2.7 FISHERIES AND WILDLIFE RESOURCES

The following sections summarize the fisheries and wildlife resources in the CFR and BFR study areas (see Appendix F for a more complete review of this topic).

2.7.1 Introduction

Fish and wildlife resources in the restoration project area have been altered. Milltown dam has changed the aquatic habitat from a riverine environment to a reservoir or more lake-like, environment. This alteration has, in turn, changed the fish and wildlife that use the area, although the effects have undoubtedly been more profound on the fisheries resources.

2.7.2 Historical Fisheries Resources

The fisheries of the CFR and BFR have experienced a multitude of environmental changes since the early 1800s when the Lewis and Clark Expedition documented fish and wildlife species in western Montana. Watershed development, including mining and smelting operations, fish species introductions, and angling have altered the fish community that historically inhabited the CFR drainage. The contemporary fish assemblage is a reflection of the anthropogenic changes that have occurred in the watershed over the past 200 years. The presence of Milltown Dam has been an influential landmark at the confluence of the CFR and BFR since its construction in 1907. The dam has altered the historical physical and biological processes that once characterized the CFR and BFR.

Historical accounts of fisheries resources in western Montana focus on westslope cutthroat trout and bull trout, suggesting the importance of these species to early settlers

as documented in numerous accounts of expeditions and surveys, including Lewis and Clark (1805), the Northern Pacific Railroad Surveys (1853), and Mullen (1863). Westslope cutthroat trout, and undoubtedly other species, provided food for the early expeditions through the Missoula Valley.

The historical fish assemblage of the middle CFR Drainage included ten species. Families comprising the fish community included salmonidae (bull trout *Salvelinus confluentus*, westslope cutthroat trout *Oncorhynchus clarki lewisi*, and mountain whitefish *Prosopium williamsoni*); catostomidae (largescale sucker *Catostomus macrocheilus* and longnose sucker *C. catostomus*); northern pikeminnow *Ptychocheilus oregonensis*; cyprinidae (longnose dace *Rhinichthys cataractae*, peamouth *Mylocheilus caurinus*, and redside shiner *Richardsonius balteatus*); and cottidae (slimy sculpin *Cottus cognatus*).

2.7.3 Historical Wildlife Resources

Specific historical data for wildlife was not researched for this report, however, the same historical accounts as referenced in the Fisheries section provided some information on the historical wildlife resources. It is likely that many of the wildlife and birds species presently found in the CFR and BFR drainages also inhabited the region in historical times. Because wildlife and bird populations are dependent on vegetation communities, it is to be expected that wildlife in general were more common historically than they are at present.

Fire and periodic flooding would have influenced the distribution of habitat patches on the floodplain and upland environments. Remnant river channel oxbows and other floodplain wetlands would have supported many waterfowl species and secretive marsh birds. Migratory species including sandhill cranes *Grus canadensis*, would have used the wetlands as a stopover in migration. Larger areas of riparian vegetation would have meant a decrease in the amount of edge habitat (the border between riparian and prairie and agriculture habitats). Raptors and other species would have inhabited the floodplain and nested in mature cottonwoods. Snags provided nesting sites for cavity-nesting species including owls and woodpeckers.

Large ungulates including elk *Cervus elaphus*, moose *Alces alces*, mule deer *Odocoileus hemionus*, and whitetail deer *Odocoileus virginianus*, occupied the restoration project area. Carnivores including mountain lions *Felis concolor*, and wolves *Canis lupis*, would have preyed on ungulates. Black bears *Ursus americanus*, grizzly bears *Ursus arctos horribilis*, coyotes *Canis latrans*, and other small mammals would have also inhabited the confluence area in historical times. Beaver *Castor canadensis*, would have influenced the distribution and character of wetlands and off-channel habitats connected to the CFR.

2.7.4 Existing Fisheries Resources

The CFR and BFR maintain important fisheries in western Montana. Substantial efforts have documented the effects of Milltown Dam and the contaminated sediments deposited behind the dam, on the fish community including the influence of the dam on fish passage, habitat degradation, and enhancing conditions for deleterious introduced species including northern pike *Esox lucius*.

The fish community of the CFR and BFR has become more diverse over time with the introduction of non-native species. In addition to the ten native species that were listed in the preceding section, eight additional species have been added to the historical fish community. Introduced species include northern pike *Esox lucius*, largemouth bass *Micropterus salmoides,* eastern brook trout *S. fontinalis,* rainbow trout *O. mykiss*, brown trout *Salmo trutta*, yellow perch *Perca flavescens*, white suckers *C. commersoni*, and pumpkinseed *Lepomis gibbosus*.

2.7.4.1 Effects of Milltown Dam and Reservoir on the Fish Community

There are three primary effects of Milltown Dam and the reservoir on the fish community. First, the dam has served as a fish passage barrier to migrating fish since it was constructed in 1907. Secondly, contaminated sediments that are stored behind the dam are periodically scoured and discharge downstream. Mobile heavy metals and arsenic within the deposited sediment negatively affect the fish community in and downstream from Milltown reservoir. Lastly, Milltown Dam has created a reservoir environment that has provided beneficial habitat for northern pike. Studies completed by MFWP have determined that northern pike prey on bull trout and westslope cutthroat trout in addition to other sport fishes including rainbow trout.

Milltown Dam as a Fish Passage Barrier
The function of Milltown Dam as a fish passage barrier is well documented (Swanberg, 1997; McEvoy, 1998; Schmetterling and McEvoy, 2000; Schmetterling and McFee, *in review*). The location of the dam effectively impacts 11 fluvial fish populations from both the CFR and Blackfoot drainages (Schmetterling, 2003). Due to the long period of time that the dam has been in place, it has likely had a negative effect on fluvial life history forms

Loss of fish from upstream populations happens when fish pass over the dam but are unable to return to their natal tributaries or main stem habitats (Schmetterling and McEvoy, 1999; Schmetterling, 2003). Loss of these fish from upstream waters may affect nutrient cycling, food web interactions, and fish population One tributary stream within the restoration project area, Deer Creek, has been identified by MFWP as an important spawing stream from fluvial cutthroat trout (Pat Saffel, MFWP, pers. comm.). This stream must maintain connection to the CFR to sustain this population.

Contaminated Sediment Discharge

Sediments stored behind Milltown Dam have varying levels of heavy metal and arsenic contamination. The 1908 flood of record mobilized a large volume of mining and milling wastes from the Upper CFR watershed and deposited the material upstream of Milltown Dam (USEPA, 2004). Periodic scouring of deposited sediments during elevated runoff events and/or ice floes have caused the discharge of contaminated materials to the CFR downstream from the dam causing acute and chronic effects downstream. Discharge of contaminated sediment was implicated in causing major population declines downstream of Milltown Dam following the 1996 ice floe and runoff event on the BFR and CFR following draw down of the reservoir that was necessary to protect the dam from ice scour (USEPA, 2004; Knotek, 2005). Copper levels measured in the ensuing flood were elevated to concentrations nearly 17 times greater than the baseline value for acute levels (Montana DEQ, unpublished data, 1997 *cited in* Knotek, 2005). The population decline appeared to last approximately 6 years as rainbow and brown trout densities recovered to near their long-term averages by 2002.

Milltown Reservoir and an Altered Riverine Environment

Milltown Dam has converted the confluence of the CFR and BFR into a slow flowing aquatic environment characterized by expansive backwater channels, wetlands, and low water velocities. Although the dam has created diverse aquatic habitat, it has also provided habitat for northern pike. Northern pike were first detected in the CFR downstream of Milltown Dam in 1999 (Knotek, 2005). It is believed these fish were derived from an illegal introduction of northern pike into the Clearwater River drainage (a tributary of the BFR) in the early 1990s (Schmetterling, 2001). Maintenance of a stable reservoir environment provides ideal conditions for pike spawning and juvenile rearing. Pike found in the CFR downstream from the dam are assumed to be emigrants from the upstream reservoir.

2.7.5 Existing Wildlife Resources

The existing wildlife species inhabiting the CFR and BFR confluence area reflects both the historical community and the effects of Milltown reservoir and river corridor development. The contiguous riparian vegetation assemblages that historically characterized the river corridor are now affected by contaminated mining wastes from upstream, land development, the transportation corridor, and agricultural use of the historical floodplain. These impacts have converted the contiguous plant communities to smaller patch sizes that are less resilient to noxious weed invasions and environmental fluctuations (fire and floods), and offer more simplified habitat for birds and wildlife.

Although habitat modifications have affected some bird species, waterfowl may have benefited from the extensive backwaters and wetlands created by Milltown Dam. Waterfowl, such as grebes, herons, swans, ducks, cormorants, and mergansers; raptors such as hawks, eagles, osprey, and kestrels; and song birds and other bird species, such as doves, pheasants, hummingbirds, and woodpeckers are found throughout the restoration project area (EPA, 2004).

Mule deer, white tail deer, moose, black bears, coyotes, and other small mammals continue to reside in the restoration project area. Grizzly bears and elk may infrequently migrate through the restoration project area. Wolves are not known to inhabit the area although they are found throughout the region.

2.7.6 Fisheries Resources Desired Future Conditions

The desired future condition for the CFR and BFR fisheries includes re-establishing fish passage through the restoration project area, further reducing pike population densities, and realizing the full expression of fish life histories (i.e. allowing free migration). Removal of Milltown Dam and some of the contaminated sediment stored behind the dam will help address the desired future condition goals. Continued monitoring of the project by MFWP will evaluate how native and introduced species respond to the dam removal and planned channel restoration efforts.

2.7.7 Wildlife Resources Desired Future Conditions

The RP aims to re-establish a free-flowing river and adjacent floodplain environments through the restoration project area. Floodplain reconstruction will grade the floodplain to create diverse topography and a range of wetland types including open water ponds, discontinuous floodplain channels, and backwater habitats. An intensive revegetation plan (see Appendix G) is proposed to initiate vegetation recovery following channel and floodplain reconstruction. Increasing the long-term patch size of forest and shrub habitats, reducing the amount of edge between riparian and developed areas, and ensuring no net loss of mature, deciduous-forest downed wood and snags of all sizes will benefit restoration efforts and speed ecological recovery. Removing Milltown Dam and restoring the CFR and BFR migration corridors is expected to benefit migratory wildlife species. Rebuilding the river channels and floodplain will also expand the width of the migration corridor. Long-term vegetation recovery will also improve corridor conditions.

2.8 PRELIMINARY INFRASTRUCTURE ASSESSMENT

Six existing bridges within the restoration project area were considered in the RP. Five bridges are located in BFR1 including the two Interstate 90 bridges, the BNSF railroad bridge, the State Highway 200 bridge, and the decommissioned Missoula County bridge that is now limited to pedestrian traffic. A second BNSF railroad bridge is located in CFR1 downstream of Milltown Dam. Other important infrastructure in the restoration project area includes Stimson Dam, the Interstate 90 highway embankment in CFR2 and BFR1, secondary roads in the transportation corridor, and land development paralleling the river.

It is unknown how existing infrastructure will perform after dam removal Upon removal of the dam, existing infrastructure will be exposed to free flowing river characteristics such as higher shear stress, higher velocity, deeper channel scour, ice floes and debris passage. Existing infrastructure should be evaluated for the effects of dam removal on infrastructure stability. These issues are identified in Appendix H.

2.8.1 Infrastructure Constraints and Effects of Restoration on Stability

Existing bridges in the restoration project area were evaluated to determine the potential limitations posed on the RP. A brief field review of the bridges was conducted to photograph the structures, measure span lengths and identify pier locations. Based on the field review, it was determined that the five BFR bridges could adequately span the proposed minimum 240 ft floodplain width of the BFR without causing a constriction and localized increase in water surface. The railroad bridge in CFR1 has an adequate span to accommodate the proposed channel and floodprone area of 300 ft. In addition, adequate freeboard appears to be available for all bridges during a 100-year flood event. However, each bridge contains one or more piers that would lie within the proposed channel. Two abandoned piers near the decommissioned County bridge are recommended for removal. Piers located in the channel could experience scour and debris accumulation during ice floes or flood events. For this reason, a bridge scour and ice analysis should be completed. In anticipation of the need for scour mitigation, proposed scour mitigation and flow redirective structures are presented in Section 4.0.

Phase 3 design will encompass the floodplain analysis, bridge scour analysis, and ice analysis. Based on the proposed restoration grading plan a hydraulic model will be created to evaluate hydraulic properties in the restoration project area. Of particular interest to infrastructure will be effects of water surface elevations and flow velocities on stability. The model will also be used to estimate bridge scour including contraction scour, abutment scour and pier scour. Based on results, proposed scour mitigation structures will be modeled to achieve an appropriate level of scour protection. The model will also be used to evaluate the effects of ice jams on flood stage.

Currently, other efforts are evaluating similar issues. As part of RA, Envirocon has completed a preliminary scour analysis for interim conditions during construction (Envirocon, 2004b). The preliminary scour analysis addressed the potential scour of reservoir sediments in the CFR and BFR during reservoir drawdown and dam removal. As expected, results indicated that the BFR would scour existing fine-grained reservoir deposits. In addition, results indicated that general bed scour would be arrested by the historical coarse-grained channel bed at a location downstream of the BFR bridges. However, results predicted excessive local scour at bridge piers and abutments, raising concerns over post-dam removal infrastructure stability.

The EPA and U.S. Army Corps of Engineers are evaluating ice effects associated with dam removal. Representatives from the U.S. Army Research and Development Center Cold Regions Research and Engineering Laboratory will evaluate ice effects for existing conditions and proposed restoration conditions. Efforts will focus on evaluating locations for potential ice jam formation, ice jam effects on flood stage and scour potential. A preliminary review of historical ice events is included in Appendix C. Efforts will be made to coordinate Phase 3 hydraulic modeling and grading plan design with ice analyses.

2.8.2 Infrastructure Protection

Appendix H identifies potential bridge scour countermeasures. By setting forth these potential counter measures, neither the authors nor the State mean to imply that it is the State's responsibility to pay for the implementation of these counter measures. The State believes that implementation of bridge scour mitigation is a remediation responsibility. Where bridge piers and abutments will be exposed to free flowing river conditions on the BFR and CFR, W-weirs could be placed upstream of bridges as flow re-direction structures. W-weirs are designed to split the flow around a pier thus creating an area of lower shear stress and reduced local scour at the pier. The structure's vane arms adjacent to the banks mitigate contraction scour in a similar manner by redirecting the flow toward the openings between piers. Results of laboratory experiments (Johnson, et. al., 2001) showed that vanes appropriately placed in a stream channel upstream of a vertical wall bridge abutment moved the abutment scour away from the bank and toward the center of the channel. The same experiments developed parameters for structure orientation that maximize the benefits of flow re-direction. In addition, the experiments concluded that the structures performed effectively over a range of flow conditions.

Use of protection measures such as riprap should be minimized due to conflicts with restoration objectives. Due to risk level and cost, it may be necessary to use riprap in certain areas. In these cases, it may be possible to incorporate bioengineering and vegetation into riprap embankments. Treatments will be explored on a site-specific basis in the Phase 3 design.

2.8.3 Proposed Infrastructure

Restoration objectives focus on limiting floodplain development that could adversely affect river and riparian corridor function. Possibilities exist to construct low impact infrastructure within the restoration project area such as trails, educational exhibits and pedestrian bridges. Efforts were made to identify a potential location for a new pedestrian bridge within the restoration project area. It is assumed that this bridge would be used for non-motorized traffic, such as pedestrians,cyclists and horses. One potential location is the Duck Bridge site. Due to encroachment on the floodplain, the old approach embankments associated with this bridge have been recommended for removal. A new pedestrian bridge should be designed to span the bankfull width of the CFR at this location to minimize disruption of the flows and sediment transport in the active channel. The bridge piers should be outside the active channel and there should be floodplain available within the bridge span. This will reduce the risk of bridge scour and adverse effects on the channel. These criteria would result in a minimum bridge span of approximately 225 ft. Since the floodplain at this location is approximately 900 ft in width, the pathway leading to the bridge could be set at floodplain grade, while the bridge and its approaches could be set at least 3 ft above the 100-year flood elevation to allow clearance for ice and debris during floods.

SECTION 3 RESTORATION STRATEGIES

3.1 INTRODUCTION

The main report and other appendices to the report describe the historical, existing, and desired future conditions of the CFR and BFR restoration project area. The following section details the proposed restoration strategies and techniques that will be employed to move the existing condition toward the desired future condition. In the context of this section, the term "restoration" refers to the return of the CFR and BFR to conditions similar to their predicted historical condition within the project constraints that are outlined in Section 1.0. The provided definition follows the definition of restoration presented by the USEPA (2000), wherein, restoration refers to the return of a degraded ecosystem to a close approximation of its remaining natural potential. Project constraints, numerous anthropogenic-related changes in the restoration project area, and larger system-wide conditions (e.g. noxious weed invasion) make converting the restoration project area to an exact replica of the historical condition impossible. Rather, the proposed restoration plan will emulate what are believed to be a close rendition of the historical conditions while accounting for the project constraints.

Proposed restoration strategies are based on a multi-disciplinary effort that addresses system hydrology, geomorphology, fisheries, botany, and wetlands. Implementing a broad-based interdisciplinary approach to large scale restoration projects is considered essential for restoration project success (Shields et al. 2003). Project engineering is also a critical component of the restoration strategy. Engineering will be employed for developing the site specific restoration plans (Section 4.0) necessary for minimizing project risk, for protecting restoration project area infrastructure, and stabilizing contaminated sediments to be left in-place on the CFR floodplain. These constraints do not allow for restoring the CFR to a state of dynamic equilibrium wherein the channel is allowed to meander across its floodplain through erosion and depositional processes. The State determined that allowing for river meandering in portions of the restoration project area would not be acceptable. Maintaining vertical and lateral channel stability will be necessary to reduce risks associated with mobilizing contaminated sediments.

The restoration strategies are designed to achieve the restoration objectives established by the State of Montana and the other Trustees. Restoration objectives include the following items.

- Restore the CFR and BFR in the Milltown Reservoir Sediment Operable Unit (MRSOU) to be naturally functioning and self-maintaining.
- Use native materials to the extent practical, for stabilizing channels and the floodplain.
- Improve water quality by stabilizing contaminated sediments to be left in-place.
- Provide high quality habitat for fish and wildlife.
- Maintain existing infrastructure stability.
- Improve aesthetic values in the area by creating a diverse, natural setting.

- Provide recreational opportunities such as river boating, fishing, and trail access for hiking and bicycling.

This section describes the set of tools that we will use to meet these objectives. Section 3.2 focuses on strategies and techniques for restoring the CFR and BFR channels, the floodplain, and side channels in the restoration project area. Section 3.3 presents strategies and techniques for restoring riparian plant communities and wetlands on the CFR floodplain.

3.2 RIVER AND FLOODPLAIN RESTORATION STRATEGIES

The presented channel design techniques follow the premise of natural channel design whereby the restoration design is based on constructing a channel with appropriate dimensions to convey the sediment and discharge related to the channel-forming discharge. The channel form is affected by independent variables of discharge, sediment supply, and boundary conditions including riparian vegetation and large woody debris. Dependent variables that are a reflection of the watershed and local conditions include the channel cross-section dimensions, channel slope, and channel planform. Determining the appropriate dimensions of the dependent variables is the challenge of the restoration design. The following section introduces the methods that were used in developing the draft restoration design.

3.2.1 Channel Design Techniques

Understanding the historical, existing, and potential channel and floodplain conditions and the processes that form those conditions is essential for developing a successful restoration strategy. To maximize the potential for restoration success, three channel design approaches were used. The approaches include analog, empirical, and analytical techniques (Skidmore et al., 2001).

The proposed design is a culmination of analog, empirical and analytical methods analyses. The following information outlines the methods that were used to develop the design dimensions. Reference reach data (analog method) formed the foundation of the proposed design. Analytical techniques tested and fine-tuned the preliminary dimensions developed from the analog method. Empirical equations incorporating the reference reach data validated the proposed design channel plan form as well as presented a range of potential channel cross-section design dimensions.

Analog, empirical, and analytical methods used to evaluate existing channel conditions, were also used to predict the likely historical plan form morphology of the Clark Fork River upstream from the Blackfoot River confluence. First, the selected reference reaches (river reaches perceived to be in a stable state) were surveyed to evaluate existing conditions. Existing channel conditions (river reaches that have departed from the perceived stable state) were modeled using analytical methods to investigate channel hydraulics and sediment transport. Channel cross-sections surveyed on reference reaches and existing condition reaches from both the Clark Fork and Blackfoot rivers were modeled in HEC-RAS. Modeling results were compared to determine channel departure from perceived stable state conditions.

The reference reach data were also applied to develop a range of design channel dimensions for the project area. Analytical techniques (e.g. HEC-RAS models, Shields equation) were used to

evaluate channel conveyance, hydraulic roughness, and sediment transport. Reference data were also entered into empirical equations used to predict likely sediment transport, channel cross-section, slope, and plan form attributes.

Lastly, the reference data provided the basis for evaluating the likely historical and potential future channel plan form dimensions in the project area. Empirical equations developed by Wolman and Leopold (1957) and more recently by Millar (2000; 2005) were used to address the likely historical plan form of the Clark Fork River upstream from the Blackfoot River confluence. Reference reach data that were used in these equations included channel cross-section dimensions, the bankfull channel slope, sediment particle size information, and riparian vegetation conditions.

3.2.1.1 Channel Design Methods

Analog Methods

The analog method includes collecting field data from river reaches displaying stable channel conditions or reference characteristics. Stable reference reaches are surveyed to characterize channel cross-section, planform, and profile dimensions. Examples of best possible conditions may include the following characteristics among other attributes:

- Efficient sediment transport whereby bank erosion and sediment deposition are balanced.
- Riparian vegetation is characterized by dense communities that provide bank stability, contribute woody debris to the channel, and provide riparian and aquatic habitat diversity.
- Channel dimensions are sized to efficiently transport the available sediment load, convey the bankfull discharge, and allow flows exceeding the bankfull discharge to access an adjacent floodplain.
- Maximization of channel length given the valley slope, bed sediment particle size distribution, and riparian vegetation condition (Millar, 2005).

Dimensionless coefficients are developed for the channel dimensions, planform, and profile. Calculated coefficients may be used to compare different surveyed reaches and for developing restoration design dimensions. The dimensionless coefficients are used with average channel features (e.g. average slope, mean riffle depth) to calculate ranges of design dimensions.

Empirical Methods

Empirical methods are based on professional experience and observation, but are based on larger data sets rather than the local conditions that are evaluated using the analog method (Skidmore et al. 2001). Regime equations and regional hydraulic geometry relationships are used to predict hydraulic properties. A river in regime is considered to be stable and is in dynamic equilibrium with it sediment supply and discharge delivered by the watershed. The river may not necessarily be “locked” into one configuration, but will tend to maintain its average dimensions over a period of time and space as the channel erodes its banks, builds a floodplain, and develops diverse floodplain habitats (Millar, 2000). Regime equations generally relate channel width, depth, and slope to independent variables including bed particle distribution, discharge, or

riparian condition (Leopold and Maddock, 1953; Hey and Thorne, 1986; Van den Berg, 1995; Millar 2000; 2005). The evolution of regime equation theory continues to be a developing field.

A hydraulic geometry assessment was completed for the selected reference reaches and proposed project reaches. The assessment compared results predicted by applicable regime equations with measured values from selected reference reaches. Average results were used as guidance for developing width-depth ratios for proposed channel cross sections. Efforts focused on developing stable riffle cross section dimensions.

Analytical Methods

Analytical approaches, considered to be "process-based" methods of channel design, are based on the premise that channels can be defined by a limited number of independent and dependent variables (Skidmore et al., 2001). Due to the large number of variables (15 as cited in Skidmore et al., 2001), not all of the variables can be feasibly accounted for in formulating restoration designs. To account for this limitation, three groups of equations are used to evaluate sediment transport, bed resistance, and channel continuity. Analytical methods may be used to predict the following variables (Skidmore et al., 2001), 1) sediment load and sediment budget calculations; 2) discharge durations or discharge return intervals; and 3) channel geometry dimensions.

Hydraulic models are used to evaluate channel stability and minimum channel slope that is necessary to convey the expected range of discharge and sediment conditions. Analytical modeling is used to evaluate both existing and design channel conditions. This comparison of existing and proposed channel states is also necessary for evaluating sediment transport continuity through a transitional channel reach.

Due to theoretical assumptions and limitations that are unique to each of the aforementioned channel design methods, an unacceptable range of answers typically results. Therefore, the standard channel stability assessment involves using a combination of several methods and relying on experience, practicality, and judgment to interpret the results. Finally, applying the analytical methods to the final design dimensions is necessary to ensure that the channel's dimensions, profile, and planform (the dependent variables) are in equilibrium with the discharge, sediment supply, and boundary conditions (the independent variables) characterizing the restoration project area.

3.2.1.2 Channel Design Results

Analog, analytical, and empirical methods were used to develop the design channel dimensions. In short, analog or reference reach data were used to develop a range of potential dimensions based on channel slope, bed material, and bankfull discharge. Analytical methods were used to model the reference reach channel dimensions and to design appropriate dimensions to convey the expected discharge and maintain sediment transport. Empirical method results were compared to both the reference reach data and the analytical results to validate the design dimensions. The following sections provide additional detail on this iterative process.

Analog Method Results

Reference reach data were collected from several reaches in the CFR and BFR drainages (see Appendix B for complete geomorphic descriptions). Reference reaches included CFR3-B, the Bandmann Reach, Bonner Gage, and the Ovando Reach. Channel cross-section and profile dimensions measured in the reference reaches were converted to dimensionless coefficients by dividing bankfull channel values by an appropriate dependent variable. For example, the bankfull pool area was divided by the average riffle area to calculate a dimensionless ratio for pool area. Dimensionless ratios are provided in Appendix H.

The dimensionless coefficients were then used to develop draft channel dimensions for the restoration project areas. Conversion from the dimensionless coefficients to channel area and distances was completed by multiplying the coefficients by the appropriate channel variable. For example, pool area was determined as the product of the pool area dimensionless coefficient multiplied by the design riffle area. Pool design dimensions (Table 3-1) and riffle and run design dimensions (Table 3-2) are included below. Additional design dimensions are provided in Appendix H.

Table 3-1. Calculated pool dimensions for the restoration project reaches based on respective reference reach source coefficients.

	Riffle Area	Riffle Depth	Riffle Width	Pool Area (ft^2)			Pool Max Depth (ft)			Pool Width (ft)		
Reach (Source Coeffs)	(ft^2)	(ft)	(ft)	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
CFR3/CFR2 C (CFR3)	550	3.7	148	622	473	776	8.7	8.5	8.8	148	138	172
CFR3/CFR2 C (Ovando C)	550	3.7	148	528	435	594	9.0	7.2	12.3	123	107	133
CFR2 B (Ovando B)	530	3.6	146	583			9.4			131		
CFR2 B (Bonner B)												
BFR1 (Ovando F)	960	4.9	196	1238	1210	1277	11.1	10.4	11.8			
BFR1 (Bandmann F)	960	4.9	196	1440	864	1920	25.5	24.5	26.5	141	123	163
CFR1 (Ovando F)	1480	6.1	243	1909	1865	1968	13.8	12.9	14.7			
CFR1 (Bandmann F)	1480	6.1	243	2220	1332	2960	31.7	30.5	32.9	175	153	202

Table 3-2. Calculated run and riffle dimensions for the restoration project reaches based on respective reference reach source coefficients.

	Riffle Area	Riffle Depth	Riffle Width	Run Max Depth (ft^2)			Run Width (ft)			Riffle Max Depth (ft)		
Reach (Source Coeffs)	(ft^2)	(ft)	(ft)	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
CFR3/CFR2 C (CFR3)	550	3.7	148	9.0	8.9	9.1	129	121	135	5.6	4.5	7.2
CFR3/CFR2 C (Ovando C)	550	3.7	148	6.5	5.0	8.5	135	117	152	5.2	4.5	5.7
CFR2 B (Ovando B)	530	3.6	146	6.3	5.1	7.6	117	117	123	5.1	4.5	5.9
CFR2 B (Bonner B)												
BFR1 (Ovando F)	960	4.9	196	8.1			186			7.8	6.4	9.2
BFR1 (Bandmann F)	960	4.9	196	9.3	8.8	9.8	153	151	155	7.0	6.6	7.3
CFR1 (Ovando F)	1480	6.1	243	10.1			231			9.7	8.0	11.5
CFR1 (Bandmann F)	1480	6.1	243	11.6	11.0	12.1	190	187	192	8.7	8.2	9.0

The analog results provide a range of channel cross-section, profile, and planform dimensions for the restoration project areas. The reference reach results offer in some cases a wide range of potential channel dimensions that were evaluated along with the empirical and analytical results. Additional discussion of the reference reach design dimensions is included below in the context of the results derived from the other methods.

Empirical Method Results

Results produced a wide range of values. As mentioned previously, differences in experimental conditions under which the equations were developed is a likely cause for the variability. However, the average of all methods when compared to actual reference reach values produced an acceptable range of values. When selecting design values for modeling, consideration was given to regime equations however, greater emphasis was placed on observed values from reference reaches.

Analytical Method Results

The following section includes summary modeling results for the analytical methods employed to evaluate the existing reaches and the proposed channel dimensions. Proposed channel dimensions were generally derived from analog, empirical, and analytical modeling results. For a more detailed description of the analytical methods and results, see Appendix C.

Stable Slope Analysis

Methods for estimating stable channel slope predict slopes that correspond to a threshold hydraulic condition for the initiation of movement for a specific bed material size class. As such, available equations rely on input data for bed composition, mean depth and dominant discharge. Results indicate that observed average slopes are less than estimated stable slopes for nearly all methods and all reaches. Since the selected reference reaches are stable and do not appear to be aggrading, it can be concluded that a range of acceptable slopes is available for the proposed design reaches. Most selected design slopes are within the acceptable range for stable slope. For those values less than the acceptable range, it may be necessary to adjust other hydraulic variables such as width-depth ratio so that the proposed channel does not experience aggradation. For those values greater than the acceptable range, it may be necessary to increase the frequency of grade control structures or increase the width-depth ratio.

Bed Resistance and Channel Velocity Analysis

Channel velocity is a function of channel slope, channel geometry, and channel roughness. Available methods for estimating critical velocity predict mean velocities that correspond to a threshold hydraulic condition for the initiation of movement for a specific bed material size class. As such, available equations rely on input data for bed composition, mean depth and slope.

Channel roughness was used to estimate critical velocities in order to validate proposed channel velocities and compute proposed channel cross-sectional area. For this analysis, it was assumed that available bed material in the restoration project area will resemble that found in the corresponding reference reaches. As with other models, these equations have limitations of applicability. Many have been developed for the purpose of designing armored flood control

channels. Also, some equations incorporate factors of safety to ensure that bed movement does not occur.

Results yielded an acceptable range of velocities for bankfull discharge conditions. Existing project constraints and required tie-in points throughout the restoration project area dictated the values for the selected design slopes. Variations in slope between reference reaches and project reaches account for the difference between average calculated mean velocity and selected design mean velocity.

Despite these limitations, selected design velocities lie within the acceptable range for mean velocity. For those values less than the acceptable range, it may be necessary to adjust other hydraulic variables such as width-depth ratio so that the proposed channel does not experience aggradation. For those values greater than the acceptable range, it may be necessary to increase channel roughness with larger substrate or increase the width-depth ratio.

Critical Shear Stress Analysis

A critical shear stress analysis was completed for selected reference reaches. Hydraulic models were developed using HEC-RAS (USACE, 2004) to estimate average total shear stress. As indicated previously, the model was calibrated by using field-surveyed channel geometry, bankfull indicators, and bankfull discharges to predict Manning's roughness values.

Most available methods for calculating critical shear stress use the Shields equation, but differ in their means of calculating critical dimensionless shear stress. There are numerous critical dimensionless shear stress equations that have been developed to predict incipient motion. Equations are generally derived from laboratory flume experiments that use sand bed channels to develop sediment transport relationships. Models based on field data collected in alluvial, gravel-bed rivers are less common.

Results yielded an acceptable range of critical shear stress values for bankfull discharge conditions. When compared with actual shear stress values, average critical shear stress values correspond closely to actual shear stress at Q_2 indicating that incipient motion is likely to occur at discharges slightly above bankfull. Assuming that the bankfull discharge is responsible for incipient motion, it could be concluded that the reference reaches are experiencing aggradation although significant aggradation was not observed in the reference reaches and variation among the results could indicate that dynamic equilibrium can occur within a range of shear stress values. In fact, the higher critical shear stress could be a result of bed armoring which was observed at all sites. Assuming similar bed composition for the proposed design reaches, design shear stress values at Q_{bf} are within the range of average critical shear stress values calculated in the reference reaches.

Sediment Transport Analysis

There are numerous equations that have been developed to predict sediment transport rates. Equations are generally derived from laboratory flume experiments that used sand bed channels to develop sediment transport relationships. Models based on field data collected in alluvial, gravel bed rivers are less common. Applied methods were selected for their applicability to gravel bed rivers.

Sediment continuity analyses were completed through a comparison of average sediment transport rates (all methods) for the selected reference reaches and proposed design reaches. Modeling results provided a wide range of values for sediment transport rates. As indicated previously, this is common with sediment transport analyses. Results were found to be sensitive to slight changes in input variables. Given this sensitivity and unacceptable range of values, conclusions focus on degree of sediment continuity between upstream and downstream reaches. Results for existing and proposed conditions indicate that sediment transport capability increases in the downstream direction, implying that conveyance is adequate and reaches are not aggrading.

In summary, a range of 3 to 30 percent difference in average sediment transport capability was observed. Again, this range is attributed to the sensitivity of the methods to slight changes in input variables and transitions in valley morphology. Except for existing conditions results, the percent difference of sediment transport between reaches was observed to increase as discharge increased. Results for Q_{bf} and Q_2 produced the lowest range of reach-to-reach sediment transport differences. Given the sensitivity of the methods and range of differences for existing conditions (21 to 23 percent), the analysis appears to provide an adequate demonstration of sediment transport continuity between upstream, restoration project area and downstream reaches. However, further review of effects of sediment transport discontinuity will be evaluated during the final design.

Bend Scour Analysis

A scour analysis was completed for the proposed project reaches to evaluate general scour and bend scour. General scour was analyzed to determine the required scour depth to re-form the armor layer in the new channel. Bend scour was analyzed to validate maximum pool depths. Results for predicted channel armoring are contained in Appendix C.

Bend scour results yielded an acceptable range of values for bankfull discharge. Except for the CFR1 Bandmann reach, average results corresponded closely with observed maximum pool depths in the reference reaches. The observed maximum pool depth in the CFR1 Bandmann reach occurred on the outside of a bend near a bedrock outcrop. A similar bedrock outcrop is present in the proposed CFR1 design reach near the dam. For this reason, the observed value was given greater emphasis when selecting design values. A supplemental check of 100-year scour depths was performed for the CFR1 and BFR1 proposed reaches, yielding values of 24.1 ft and 20.3 ft, respectively. Further consideration will be given to 100-yr scour depths and associated design implications in Phase 3 final design.

Modeling runs were completed to assess hydraulic and sediment transport conditions in the existing reaches and for the design channel dimensions. A more complete discussion of the models, results, and output interpretations are included in Appendix C.

3.2.2 Construction Approach and Stabilization Methods

The CFR and BFR channels will be constructed to the selected cross-section dimensions, planforms, and profiles in order to convey the flows and transport the sediment made available

by the watershed. The reconstructed channels would be designed to minimize lateral channel migration in portions of the restoration project area where the channel parallels contaminated sediments. Reconstructing the channels in the restoration project area will improve the amount of fish habitat in the restoration project area, increase the amount of river-floodplain interaction, and provide sufficient energy dissipation. A comprehensive revegetation plan will be implemented to promote a vigorous riparian community that will provide long-term bank and floodplain stability, riparian and aquatic habitat, and woody debris recruitment to the river.

A two-stage channel will be constructed through the restoration project area. A two-stage channel includes a bankfull channel to convey the flow and sediment associated with the channel-forming discharge event, and a floodplain designed to accommodate flows of greater magnitude, including the 100-year flood. Channel-floodplain interaction would reduce in-channel water velocities, shear stress, and bank erosion at higher discharges. Constructed floodplains would serve to moderate flood peaks, store fine sediment, and increase late-season base flows.

Bank stabilization, grade control, and fish habitat structures will be constructed using large woody debris, angular rock, and coarse alluvium (see Appendix L for typical structure design details). Although some bank stabilization structures will be designed to emulate naturally occurring habitat arrays found in stable stream reaches, several of the grade control structures do not have natural analogs. Higher gradient confined channel reaches on the lower BFR and CFR will be constructed with additional grade control structures. Descriptions of proposed structures are included in the following sections.

3.2.2.1 Channel Grade Control and Bank Stabilization Methods

The restoration plan for rebuilding the CFR will require stabilizing the reconstructed channel with grade control and bank stabilization structures. Maintaining both vertical and lateral channel stability will be necessary to maintain channel-floodplain connectivity and to limit the scour of contaminated sediments to be left in-place on the CFR floodplain. Structures will be placed in the range of morphological channel features to affect habitat feature stability, sediment sorting, and aquatic habitat diversity. Structures will also be used in combination and where appropriate, bioengineering techniques will be incorporated with large wood and rock structures. A discussion of bioengineering treatments is included in Appendix G.

Structure composition, placement, and size will vary throughout the restoration project area. Although most of the structures will be designed to blend with the surround river corridor, several of the larger grade control structures will be built more so for maintaining vertical channel stability than for aesthetics. The following sections highlight the types of grade control and bank stabilization structures that will be built on the CFR and BFR.

3.2.2.2 Channel Grade Control Structures

Grade control structure types and locations will vary according to specific project reaches and project goals. Structures will address bed stability concerns, increase fish habitat distribution, and provide recreational boating opportunities where appropriate.

The grade control structures will maintain the designed channel profile elevations. The structures are also designed to improve flow convergence and sediment transport during high flows. Vane arm gradient and angle from the bank affect the hydraulic head the structures create. A steeper vane arm gradient results in greater hydraulic acceleration over the structure and into the pool created by the structure. This acceleration is necessary for maintaining sediment transport through the pool and subsequently, the depth of the pool. The vane arm gradient and arm length also affect the degree of bank protection created by the grade control structure. A longer, flatter vane arm protects a greater bank distance than a short, steep vane arm.

Rootwads and other large woody debris are typically incorporated into the grade control structures to increase the habitat diversity in the pool. Woody materials are anchored in between or below the vane arms. Material positioning influences vane hydraulics and pool scour, creating a range of aquatic habitats in the restoration project area.

The designed structures allow fish passage. Fish passage is typically a concern during base flows when portions of the stream may become disconnected if the streambed is too wide and the water too shallow. Each grade control structure will be designed to have no more than 0.5 ft to 1.0 ft of drop (water surface from the structure throat to the water surface downstream) during base flow conditions. Gaps between structure rocks also allow fish passage from the pool downstream, upstream through the structure. During the majority of the hydrograph, water depths over the vane structures would be sufficient for all species and most age classes to navigate the structures.

3.2.2.3 Bank Stabilization Structures

Bank stabilization structures are necessary for maintaining bank integrity on restored stream reaches until planted vegetation is capable of providing natural bank stabilization. Structures are expected to last for a limited period of time until vegetation provides bank stability into the future. Bank stabilization structures also serve to diversify available fish habitat. Prescribed structures provide overhead cover, flow path complexity, interstitial hiding spaces, and visual separation for fish. Species and age-classes typically segregate according to these microhabitat attributes to reduce inter-size-classes and inter-species interactions.

3.2.2.4 Additional Channel Habitat Structures

Additional channel habitat structures are planned for the higher gradient, confined channel sections of the lower CFR and BFR (CFR1, CRF2 and BFR1) where the channel profiles are somewhat steeper, the valleys narrower, and the channel pattern straighter. The prescribed structures will require large rock and woody debris similar to the aforementioned grade control and bank stabilization structures.

3.3 RIPARIAN AND WETLANDS RESTORATION STRATEGIES

3.3.1 Introduction

The draft revegetation plan provides the foundation for developing the final designs. For revegetation to be successful, acknowledgement of the role that fluvial processes have in determining plant community structure on streambanks, floodplains, wetlands and associated uplands. Because these natural processes occur over timeframes that are somewhat unpredictable, our plan includes actions to make the processes more predictable. In this document, we describe different components of the revegetation process that fit into the following categories.

- Influence site potential, as determined by topography, substrate, hydrology, and interactions with other biological components, by creating conditions that will support a natural, sustainable, and dynamic distribution of plant communities.
- Anticipate and manage for invasive species that are not in balance with the natural system.
- Identify appropriate plant materials that are adapted to the local area and to the different geomorphic features in the fluvial environment.
- Anticipate the need to maintain revegetated areas during their establishment period, while leaving room for the river to adjust to its new alignment and for some areas to naturally colonize.

This revegetation plan was developed to meet the following multiple objectives.

- Re-establish a self-sustaining native plant community in balance with fluvial processes.
- Mitigate surface erosion and associated off-site impacts.
- Restore a healthy, diverse and viable edaphic (soil) environment.
- Provide for slope and bank stability while minimizing project maintenance.
- Re-establish/enhance terrestrial, riparian and aquatic habitat for dependent species.
- Inhibit the establishment of undesirable plant species including noxious weeds.
- Post-project visuals and aesthetics.

No revegetation plan is capable of precisely replicating the pre-disturbance native plant communities. Depending on the existing vegetation and the successional stage of the plant community it may not be practical, desirable or even possible to do so. This plan is designed to "jump-start" the recovery of the complex ecologic interactions and reintroduce biological diversity to the restoration project area following restoration and reclamation activities.

The restoration project area is divided into five reaches as described in Section 1.4.2. Within those reaches, areas were further divided into categories based on geomorphic setting and revegetation treatment differentiation. The individual areas were delineated through a combination of aerial photo interpretation, field visits and post-construction landscape position associated with the conceptual design. The categories include streambanks, floodplains, wetlands, and upland areas. Each category represents a geomorphic feature, and revegetation strategies described in section 3.3 are different for different geomorphic features. While the

geomorphic features within each reach are treated slightly differently (Section 4.2), the following descriptions are intended to place restoration strategies described in Section 3.3 in the context of geomorphic features within the restoration project area.

Streambanks

Streambanks were divided into depositional areas and other streambanks. Alluvial deposition areas on the inside of meander bends would be seeded with locally collected willow and cottonwood seed following runoff to mimic natural plant establishment processes. This treatment establishes an ephemeral seed bank because seeds of these species are short-lived and germinate within a brief window that is closely tied to the river's hydrograph. These dynamic depositional areas would not be treated otherwise, except under special circumstances identified during final design.

The "outside" banks of meanders require a more rigorous revegetation treatment due to their occasional exposure to high energy stream flows. These areas would be revegetated using a combination of transplanted sod and shrubs, native seed, containerized seedlings, and bioengineered bank structures integrated with large wood and rock-based bank structures described in other sections of this document. For conceptual planning and cost estimating, it is assumed streambanks are a ten-foot band along the channel; depositional areas are up to 50 feet wide.

Floodplain

The floodplain includes areas that are inundated during flood flows, but are outside the streambanks. Treatments for these areas are variable because floodplains comprise the majority of areas to be restored. Final grading will result in micro-topographic relief to create a complex floodplain surface. Much of the area should be alluvial gravel and cobble substrate, but portions of the floodplain should be covered with sand, silt loam or organic material, depending on micro-topography and distance from the river channel. Much of the floodplain will be seeded and planted with containerized seedlings. Portions of the floodplain may be amended with organic mulches to limit weed infestation and support development of biological soil components. As part of creating micro-topographic relief, some depressions will be created within the floodplain that will develop into wetland features.

Wetlands

The desired condition targets historical conditions, which was presumably a forested riparian community in an alluvial floodplain. Once the ponding effect from Milltown Dam is removed, areas currently hydrologically modified by this effect may shift to a drier plant community. The plan addresses desired future conditions for the riparian plant communities post-construction. Rather than trying to predict changes in the plant community, it will be more important to monitor those changes. The final design will include strategies to ensure native plant species, rather than weeds, colonize these areas as the hydrology shifts. It is important to note that the overall restoration goal is aimed at restoring fluvial processes that result in a range of plant communities.

Wetlands include the following habitat features.

- Abandoned channels that are retained after construction of the new channel.
- Depressions that are constructed within the floodplain as part of the final floodplain grading.
- Existing wetland features that will be maintained or enhanced to meet the project's wetland objectives.

Newly constructed wetland areas should be graded with approximately 10:1 slopes on the river side and steeper slopes on the upland side. These areas should be covered with six inches to a foot of fine-textured mineral soil or organic soil. Wetlands should be seeded with the wetland seed mix, and planted with both herbaceous plugs, and containerized riparian/wetland shrubs. Revegetation will be slightly more aggressive in these areas to limit infestation by weeds and invasive plant species.

Uplands

Uplands are areas outside of the active floodplain that will be disturbed by grading and other river restoration activities. Most upland areas will be seeded and treated with either hydromulch or a thin layer of compost to enhance seed establishment and limit weed infestations. Portions of these areas will be planted with containerized shrubs and trees suited for riparian and upland areas.

3.3.2 Plant Salvage

Mature plants located in the path of new construction and grading should be salvaged wherever possible. Salvaging plants and sod can be a relatively inexpensive method for obtaining large, native, site-adapted planting stock for rapid vegetative reestablishment and bank stabilization. During final design, shrub, tree, and sod salvage areas should be identified. In addition, holding areas should be identified, and a maintenance plan should be developed that addresses duration of salvaged material storage, timing related to other construction activities, weeding, and watering. The presence of noxious weeds and invasive plant species in salvaged plant root-balls should be considered when selecting salvage stock.

3.3.3 Final Grading

Final grading of bare site areas should result in varied elevations aimed at creating micro-topographic relief and a variety of habitat niches on the floodplain. Examples floodplain features include the following site types.

- Grade surfaces, which include areas graded to a specific elevation with no microtopography or other features incorporated. In Section 4.2, Conceptual Treatments by Reach, this type of grading is specified as either Upland or Floodplain (FP).
- Linear depositional features of sand and gravel oriented parallel to the river channel, approximately six inches to one foot above the floodplain elevation and three to six feet wide. These would be similar to windrow-like linear features naturally deposited along the Clark Fork River during high flow events. These features provide habitat for different plant species than the surrounding floodplain surface and cause smaller flood flows to scour and deposit sediment in more complex patterns than if the floodplain was

graded smooth. In Section 4.2, Conceptual Treatments by Reach, this type of grading is specified as windrow (W).

- Depression features, similar to abandoned oxbow features, to create wetland habitat between six inches and three feet below the floodplain surface. On the river side, these depressions should have no more than a 10:1 slope and on the opposite side, these depressions may have steeper slopes. In Section 4.2, Conceptual Treatments by Reach, this type of grading is specified as depression (D).
- Creation of bankfull benches and depositional features along the channel. In Section 4.2, Conceptual Treatments by Reach, this type of grading is specified as bankfull bench (BF Bench).

3.3.4 Substrate Variation

Rather than covering bare floodplain sites with a uniform layer of topsoil, substrate should be varied. This includes incorporating areas of exposed gravel and cobble, layers of sand, and areas of silt loam or organic material into the new floodplain. Gravel/cobble should be the original fill material, sand should be placed in patches on gravel/cobble surfaces, and finer-textured material should be placed six to twelve inches deep in depressions. In Section 4.2, Conceptual Treatments by Reach, substrate is denoted as either gravel/cobble (G/C), sand (S), or silt loam/ organic soil (L). Final designs will show locations of these different substrates and mulching, seeding, and planting plans should correspond to substrate polygons.

3.3.5 Weed Management

Weed management should be incorporated as part of site preparation and revegetation actions. The primary weed species have broader substrate and moisture tolerances than most of the native plant species, and they are very tolerant of disturbance; therefore, weed management on bare sites will be particularly challenging. Spotted knapweed will likely colonize higher and coarser areas within the floodplain. Tansy will likely occupy sandier areas at the active floodplain elevation. Reed canarygrass will occupy all areas within the floodplain, but will become particularly dense on finer-textured soils around the perimeter of depressions.

A well-established native plant community is more likely to resist weed invasion. Several weed management strategies should be implemented both during and after construction. In planted areas, selective weed management methods should be used to minimize damage to newly planted and seeded materials. Selective weed control methods include, manual removal (hand pulling, digging, or cutting) and spot herbicide applications (backpack sprayer or wick applications). Weed management activities should continue annually for three to five years following project completion.

It is inevitable that these weed species will infest new floodplain surfaces to some degree. However, it will be possible to prevent the new floodplain surfaces from becoming monotypic weed communities by aggressively promoting colonization of bare substrate by desired native plant species. Methods for promoting native plant species establishment on bare sites include the following techniques.

- Establish a native seed bank.
- Occupy available niches by seeding and planting desired plant species.
- Create a complex floodplain surface.
- Use a coarse, organic mulch in areas away from the channel.
- Actively manage vegetation by controlling weeds and maintaining newly seeded and planted areas.

These methods are described in greater detail in the following subsections.

3.3.6 Seeding

The revegetation effort would also include up to five native seed mixes that would be specific to landform and edaphic conditions. Seed mixes include: wetlands (including ephemeral and long-term seed bank mixes), streambanks, floodplain, and upland terraces. Availability of seed will determine the number of seed mixes that will be possible to create for the project. Seed mixes will consist of both grass and forb species. Using a mix of grasses and forbs will occupy a wider range of microsites and soil strata and help to reduce availability of open sites for weedy species to germinate and become established.

3.3.7 Plant Materials for Restoration

Trees and shrubs used in the restoration project area would be containerized native plants with an established root system. The plants should be grown in a 3-inch diameter by 14-inch long (minimum) up to 36-inch long containers or in one tall one-gallon containers, measuring 4 inches x 4 inches x 14 inches. Herbaceous species would be grown in smaller containers. Cuttings would be limited to native willow species harvested from on-site and/or nearby areas. Cuttings should be approximately 40 inches in length and 0.5 inches to 0.75 inches in diameter. Cuttings would be planted so the basal end is submerged in or very near groundwater for the majority of the year, this would increase their survival rate.

3.3.8 Planting Strategies and Methods

<u>Planting Methods</u>
Plants should be installed so roots are straight, and the root crown is level with or slightly below the surrounding soil surface. As part of the final design phase, specific planting methods should be identified for groups of plant species. For example, willow and rose family plants can be planted with stems partially buried. Alternatively, pine family plants must be planted so that the root crown is even with the soil surface. Planting methods should ensure that air pockets are eliminated during planting. Each plant should be secure enough in the ground to resist a firm tug.

3.3.9 Soil Amendments

Site preparation and revegetation strategies in this conceptual plan include some techniques for varying topography and substrate to mimic how natural processes create a complex matrix of

substrate. Soil amendments, in the context of native plant revegetation, are typically aimed at either adding nutrients or changing the texture or organic matter composition of soil surfaces. Riparian areas are natural nutrient transport zones, so nutrients will move in and out of the system without assistance from scientists. Further, because native plants are adapted to lower levels of available nutrients than non-native plant species, adding nutrients might give invasive plants a competitive edge.

Revegetation plans also often include methods for adding beneficial soil microbes including mycorrhizae. During final design, the need to add nutrients or soil microbes should be evaluated carefully. However, because sources of nutrients and mycorrhizae are probably present in the surrounding ecosystem, they are not included as specific treatments within the conceptual plan.

3.3.10 Large Wood

Because weeds thrive on simple, uniform surfaces, one strategy to limit weed infestation will be to create a complex surface. This can be accomplished by varying final grading and substrate as described above. In addition, large logs and woody debris piles can be distributed throughout the floodplain to create micro-sites and stimulate biological development within the soil. In Section 4.2, Conceptual Treatments by Reach, large wood placement is indicated as either yes or no.

3.3.11 Organic Mulches

Soils naturally protect themselves from erosion by accumulating thin layers of organic debris. The organic debris provides a food source for soil organisms. Resulting fungal nets on the soil surface, and biological activity within the rooting zone, can stabilize soils and limit weed infestations. While applying mulch would not be appropriate within areas that are frequently flooded by the river, a two-inch thick layer of either wood chips or conifer needles from native tree species should be applied in some bare soil areas less likely to be scoured by overbank flows. In Section 4.2, Conceptual Treatments by Reach, organic mulch is indicated by either a percentage of the polygon that should receive mulch or no mulch.

All seed, organic material, and other material brought onto the site will need to meet State weed-free requirements. Risk of spreading weeds will be addressed in several ways: specifications will address specific materials like compost; all materials delivered to the site will be inspected for quality and to assess whether they meet specifications; and construction best management practices will provide guidelines for washing equipment to avoid transfer of undesirable seed to the project area. Terraseeding (blowing compost already pre-mixed with seed) may also be used in select areas. Terraseeding technology is weed free based on the cooking process used on the compost production.

3.3.12 Erosion Control

Many aspects of the revegetation plan will result in relatively stable soils, in addition to meeting other revegetation objectives. For example, seeding, revegetation, and mulching all contribute to limiting erosion. Because erosion control is addressed indirectly, this plan does not describe specific erosion control methods. It is also important to consider that erosion is a necessary and

natural process in an alluvial river system, so there needs to be some allowance for alluvial material to be redistributed by the river.

3.3.13 Maintenance and Monitoring

During the first two years, bare site areas should be closely managed to limit weed infestations and maintain seeded and planted areas. Based on our experience, two years is approximately how long it takes for a site to stabilize and begin to reflect its early vegetative potential. Methods for maintenance, monitoring and management are described in G.4.16.

Some weeds can be hand-pulled with only a few person days worth of effort, in other areas where severe weed infestations occur, it may be necessary to use aggressive weed control measures and essentially start over with revegetation once weeds have been suppressed.

Even though floodplains are within a functional wetland environment, they can be extremely dry during portions of the growing season. During the first two growing seasons, all planted seedlings should be monitored for soil moisture, and deep watered to saturate the rooting zone if needed. Some seeded areas should be watered using broadcast irrigation to maximize germination and thus limit available niches for weeds.

3.3.14 Project Oversight

Revegetation should be coordinated in the field by an experienced revegetation specialist working closely with the fluvial geomorphologist. The revegetation specialist will be responsible for coordinating with the fluvial geomorphologist as well as overseeing the planting crews.

3.3.15 Monitoring and Adaptive Management

<u>Monitoring</u>
Monitoring should be aimed at determining maintenance needs and progress toward the desired condition. Monitoring may also include noting the presence and abundance of noxious vegetation, particularly where weeds have been treated within the restoration project area. Monitoring at the site will be used to develop adaptive management strategies for weed control.

<u>Adaptive Management</u>
Because plant community restoration is a long-term process, the overall project plan should allow for continued adaptation of the project maintenance plan based on monitoring results. Practically, this means budgeting a total of 10 to 20 percent of the overall revegetation cost for maintenance to be spread out over a five to ten year period after the project is initially constructed.

3.4 RESTORATION STRATEGIES SUMMARY

Analog, empirical, and analytical methods were employed to develop the draft restoration design for the CFR and BFR in the vicinity of Milltown reservoir. Data collection included a large scale

effort that documented existing and reference river corridor conditions on CFR and BFR both in the restoration project area and in surrounding reaches. Reference data were used to develop dimensionless coefficients that were in turn used to calculate potential design dimensions for the four project reaches: CFR1, BFR1, CFR2 and CFR3.

Empirical methods were also used to evaluate potential channel conditions as well as to investigate the likely historical and potential channel planform for CFR. Empirical equation results suggested that based on valley and channel slope, bank materials, and vegetation condition, the historical CFR planform was most likely described as a meandering or straight (sinuosity < 1.5) channel. Empirical equations also predicted a straight or meandering channel based on the draft channel design dimensions.

Analytical methods included modeling channel roughness, incipient particle motion, channel velocities, sediment transport, and channel scour potential. Modeling runs were conducted for the reference reaches to characterize the most optimal existing conditions. Draft design cross-section channel dimensions derived from both the analog and empirical methods were also modeled. The final draft design cross-section channel dimensions were developed from the modeling run results.

Channel planform geometry was developed from analog and empirical sources. Planform options vary by reach according to valley bottom width. Only one channel alignment option was evaluated for reaches with narrow valley bottoms, namely CFR1, BFR1, and CFR2. The more expansive CFR3 valley bottom allows more flexibility in designing the channel planform. Four potential options were developed for this reach with Alignment C being the preferred design planform. More details will be determined in the final design phase.

A comprehensive revegetation plan was outlined for the restoration project area. The plan is designed to “jump-start” the recovery of the complex ecologic interactions and reintroduce biological diversity to the restoration project area following restoration and reclamation activities.

Grade control and bank stabilization structures will be used to provide channel stability, fish habitat, and recreational boating. Structures will be built to maintain channel-floodplain connectivity, limit bank erosion where contaminated sediments are to be left in-place, and to create aquatic habitat complexity.

The companion appendices provide more detailed information on the topics presented in Section 3.0.

SECTION 4 RESTORATION PLAN

4.1 INTRODUCTION

The following sections present reach-specific recommendations for channel, floodplain and vegetation restoration. An implementation timeline is also included. Supplemental supporting information for Section 4 is contained in Appendices B, C, D, F and H.

4.2 DESIGN CRITERIA

In the absence of a standardized approach to stream channel design, the design team used a combination of elements from several techniques that represent the best available methods for developing design criteria for restoration designs. Interpreting results, measuring channel stability and establishing acceptable design thresholds relied on the experience and judgment of the designers, the application of standard hydraulic principles and not necessarily an established or accepted set of design criteria. As described in Section 3, analog, empirical, and analytical methods provided the basis for developing a range of design channel dimensions, and were used to predict the likely historical plan form morphology of the Clark Fork River upstream from the Blackfoot River confluence.

Final channel dimensions were established through a trial and error process that included several iterations of channel stability analyses. The methods used to complete the channel stability analysis are outlined in Section 3.2.1. To reiterate, the methodology focused on refining the cross section, plan form and profile dimensions until acceptable values were observed for each hydraulic parameter considered to influence the dynamic equilibrium of river hydraulics. Acceptable values were assumed to be a range of values that best achieved dynamic equilibrium among hydraulic parameters, anticipated sediment size and anticipated sediment supply. Emphasis was placed on the results of analog methods for the selection of cross section, plan form and profile dimensions with considerable consideration given to sediment supply and sediment size. A range of +/-15% around a mean value for a specific hydraulic parameter was considered to be the guideline for the variation that a newly constructed river can accommodate before dynamic equilibrium is disrupted and instability is triggered. Although a statistical analysis was not employed, this guideline, along with additional consideration of reference reach conditions, was employed as threshold design criteria for channel stability and maintaining dynamic equilibrium. For reporting purposes, only the final iteration of analyses was reported in Appendix C **–** Preliminary Channel Stability Assessment.

In terms of the analyses in Appendix C, channel stability represents a condition where several hydraulic variables are balanced to achieve a state of dynamic equilibrium that approximates reference conditions, satisfies traditional hydraulic design principles and considers results from the best available regime equations. As described on page C-14, channel stability implies that although the channel pattern may change over time, the channel's cross section area and slope remain consistent. Under stable conditions, rates of erosion and deposition are approximately balanced as the channel pattern changes.

An assessment of the selected channel dimensions over a range of discharges was completed using HECRAS and is presented in Appendix C. Hydraulic parameters derived from the analysis were used as input for calculations presented in the channel stability assessment.

4.2.1 Selected Design Dimensions

The following section includes the proposed design dimensions for the proposed restoration project area. Riffle cross-section dimensions (Table 4-1), planform geometry (Table 4-2), and profile dimensions (Table 4-3) are included below. Run, glide, and pool dimensions are included in Appendix K.

Table 4-1. Selected riffle cross-section dimensions for proposed reaches at bankfull discharge.

Channel Variable	BFR1	CFR1	CFR2	CFR2/3
Stream Type	B3c	B3c	B3c	C4
Width (ft)	186-206	231-255	138-153	141-156
Mean Depth (ft)	4.7-5.2	5.8-6.4	3.5-3.8	3.5-3.9
Maximum Depth (ft)	6.2-7.5	8.3-8.7	4.6-5.6	4.7-5.7
Area (ft^2)	960	1,480	530	550
Width-Depth Ratio	36-44	36-44	36-44	36-44
Floodplain Width (ft)	240 - 280	275 - 330	300 - 900	900 – 3,000
Entrenchment Ratio	1.2-1.4	1.1-1.2	2 - 6	6 - 20

Table 4-2. Selected pattern dimensions for the proposed project reaches.

Characteristic	BFR1	CFR1	CFR2	CFR2/3
Stream Type	B3c	B3c	B3c	C4
Meander Radius (ft)	600 – 1,000	750 – 1,250	450 - 750	450 - 750
Radius-Width Ratio	N/A	N/A	N/A	3 – 5
Meander Length (ft)	2,000 – 3,600	2,500 – 4,500	1,500 – 2,700	1,500 – 2,700
Meander-Width Ratio	N/A	N/A	N/A	10-18
Stream Length (ft)	6,000	5,500	4,000	9,500
Valley Length (ft)	5,900	5,200	3,600	7,300
Sinuosity	1.00 – 1.10	1.00 – 1.10	1.10-1.20	1.20-1.30
Belt Width (ft)	400 - 800	500 – 1,000	600 – 1,200	1,200 – 1,800
Belt Width-Width Ratio	2 - 4	2 - 4	4 - 8	8 - 12

Table 4-3. Selected channel profile dimensions for the proposed project reaches.

Characteristic	BFR1	CFR1	CFR2	CFR2/3
Stream Type	B3c	B3c	B3c	C4
Average Valley Slope (ft/ft)	0.0026	0.0031	0.0043	0.0032
Average Channel Slope (ft/ft)	0.0025	0.0030	0.0036	0.0027
Pool Spacing (ft)	800 – 1,200	1,000 – 1,500	450 - 750	450 - 750
Pool Spacing-Width Ratio	4 - 6	4 - 6	3 – 5	3 - 5

4.3 SELECTED RESTORATION STARTING POINTS AND CONSIDERATIONS

4.3.1 CFR Upstream Starting Point

The DCRP proposed starting the CFR channel restoration just upstream from Turah Bridge and extending downstream to approximately Station 28+00 on the valley profile. The rationale for starting upstream from Turah Bridge was that a stable, functioning channel segment near the upstream end of CFR3 that was considered stable enough to end the restoration effort in the long-term was not identified. Turah Bridge was selected because it was considered a stable point in the respect that it probably would not change location over time. The bridge and reach may change, but due to land ownership and access issues, the bridge location would probably be constant. It is important for the upstream end a restoration project to end at a stable point to minimize the risk that the river will change course, location or elevation immediately upstream from the project, thereby causing failure of some reach of the project.

Because the area upstream from CFR3 lies within a different Operable Unit (Clark Fork River Operable Unit), it must be treated in a different planning and budget process. There are also different landowners, objectives and less stringent requirements in terms of sediments left in place. It was decided early in the Phase 2 process that several semi-stable points would be evaluated as a starting point for the restoration effort. The objective was to select the downstream-most point that would serve as a starting point and evaluate what treatments would need to be made to minimize risks until restoration planning could commence in the upstream reach (referred to as CFR 4 in the DCRP).

Information used to determine the upstream starting point for the CFR included the topography developed for the entire restoration project area, historical aerial photo trend analysis and field review of site conditions. The first point (downstream-most point) evaluated as the upstream starting point for the CFR, is the upstream end of the CFR3-B reference reach. Based on the aerial photo trend analysis, the channel has maintained an entrance into the restoration project area at a consistent point since 1937. At no time during the nearly 70-year time span did the CFR channel flow to the north of the existing channel alignment despite substantial channel braiding in the upstream reach CFR3-A. More recently, the dominant channel has moved to the south along the railroad grade.

The field review and topography indicates that there are two floodplain swales to the north that the inverts are at or near the floodplain elevation of the existing channel (See Sheet K-9 in Appendix K, cross-section at Station 185+00). These channels have the potential to capture flood flows and downcut, thereby circumventing the starting point for the project. However, both swales are heavily vegetated with mature vegetation and the risk of capture is considered low in the short-term. The potential that the channel could migrate back north and enter the project at a different angle is still high over the long-term.

Other considerations with starting the project immediately downstream from a braided reach include sediment supply, sediment transport, and grade control. Sediment supplies will be higher with the severe bank erosion associated and channel scour with the upstream reach than if that reach were restored to a meandering, comparatively stable channel. The braided channel will deliver more bedload sediment to the restored reach, particularly during flood events. Sediment transport analyses for CFR3 indicate that the channel will transport the available sediment, but a reduced load would increase longevity and decrease potential for channel maintenance.

The proposed grade should be maintained in the upstream part of the project until the bed becomes stable and planted vegetation matures. Designing a grade control structure at the downstream end of a braided reach is challenging and any channel adjustments can cause increased upstream deposition. Increased upstream deposition could also increase lateral channel movement to the north.

In summary, the proposed starting point for the restoration at the upstream end of reach CFR3B (Station 220+00 on Sheet I-4) appears to be acceptable in the short-term, but not without risks. We recommend initiating planning efforts to continue the project upstream as soon as possible with the objective of tying into a more stable point. However, we recognize that leaving the river untreated upstream from that point imparts risk that the channel will enter the project at some other location or angle that would be detrimental to the long term stability of the project area. Also, bedload sediment sources from the reach upstream would remain high with no additional restoration work upstream from Station 220+00. Performance and stability of the final selected alignment will be conducted in the Phase 3 design process. The stability assessment, considering the existing unstable conditions remaining upstream, will provide some quantitative determination of the long term risks. In addition, to reduce the risk of the channel moving to the north, floodplain grade control structures should be considered. The need for these structures and design details will be determined in Phase 3. If the recommendation to pursue planning for the upstream reach is not feasible, then more permanent structures at the starting point should be considered in the Phase 3 design.

4.3.2 CFR Downstream Ending Point

The CFR downstream from Milltown reaches a stable point at Station 30+00. Downstream from this station, the river appears to be in equilibrium and functioning well. For this reason, the project will tie into this channel segment and match channel and floodplain dimensions and elevations. Sediment transport and flood conditions downstream from this point will be evaluated in the Phase 3 design.

4.3.3 BFR Upstream Starting Point

Several factors complicate the starting point on the BFR, including the removal of Stimson Dam, and the associated scour and bank stabilization upstream from Stimson Dam. Another factor that is somewhat unknown is the scour of bed material that will occur during Stage 3 drawdown of Milltown Dam. Scour estimates have been made by Envirocon and CH2MHill (2004), but these estimates are preliminary and are somewhat conservative. The grade control structures near the bridges will limit the extent of the scour, but the resultant bed grade and channel shape can not be predicted at this point. For these reasons, the proposed actions are phased to allow the removal of Stimson Dam and Milltown Dam and the associated scour to take place before the upstream extent and scope of the project are determined. These actions will take place in the first two years of project implementation, which allows time for design and implementation to take place later in the process. This recommendation should pose no risks for the final restoration of the BFR upstream from the bridges.

4.4 REACH SPECIFIC CHANNEL AND FLOODPLAIN RECOMMENDATIONS

The following sections provide specific details about the recommended restoration treatments for the restoration project area. Recommendations focus on treatments including stream types, rationale for proposed alternatives, grade control structures, bank stabilization structures, and revegetation. Only structures deemed critical for coordinating with the RA are addressed in detail in the following section. Such structures are identified to allow for review and comment by the peer review panel. Additional structure details will be finalized in the Phase 3 design.

4.4.1 CFR1 Proposed Treatments

CFR1 includes the CFR downstream to the Interstate 90 bridge. The RA includes removing the powerhouse, radial gates, divider block, and right abutment wing wall in addition to Milltown Dam. This will allow the construction a B3c channel with a floodprone width of approximately 600 ft. The powerhouse and associated structures will be removed to a depth approximately 5 ft lower than the proposed finished grade of the channel. The proposed CFR channel at the confluence with the BFR will bend gradually to encounter the rock cliff at which point a large grade control structure is proposed to be placed at station 50+00 to establish the gradient for the entire upstream segments of both the BFR and CFR. The grade control structure would be keyed into any remaining segments of the removed structures and wing wall to provide long-term floodplain stability. The structure would also be keyed into the existing subsurface bedrock and the rock cliff on the south side of the dam. Alternative structure designs and an evaluation of performance will be completed in the Phase 3 design.

Due to the concerns regarding grade control in relation to the infrastructure and dam removal as well as the need for more detail relative to the Consent Decree, two grade control structures were proposed at the location of the dam and just downstream. These structures were proposed in preliminary design format in order for the Settling Defendants to plan the Remediation Actions in the vicinity of the dam. The purpose of these structures is to stabilize the streambed and streambanks in vicinity of the dam. The final selected grade control structures will need to be constructed several years before the channels upstream will be completed due to the Remediation

schedule. The proposed structures are a minor cost when compared to the project costs. However, the risks of channel scour are very significant as are the project costs if bed degradation were to occur in this reach. These structures are intended to be temporary in nature until the entire bed undergoes natural sorting and armoring processes.

The riffle downstream from the dam (upstream from the railroad grade) is not an adequate grade control and will not provide the "backwater" effect necessary to stabilize the grade. The existing scour pool tailout is formed by a channel configuration that will no longer be in place. The scour pool exists due the hydraulics created by the spillway and radial gate, which will be removed. The pool downstream from the powerhouse was created by releases through the turbines. The existing pool tailout is created by complex hydraulics associated with the two release points and dam operation. The proposed plan would reshape the entire area, which will change the existing pool tailout. The existing pool tailout is not adequate to ensure grade control upstream, and thus, some grade control structures will be necessary in this reach of river. More evaluation and discussion of the structures will be completed in the Phase 3 analysis. Different structures may also be evaluated during the Phase 3 design.

The proposed alignment, gradient, channel configuration, and depth are similar to pre-dam conditions based on surveys conducted in 1905 (K. Ross Toole Archives, Montana Power Collection, University of Montana Library). The floodprone area is somewhat less than pre-dam conditions due to land development along the northern edge of the historical floodplain. The channel alignment downstream from the dam will also be similar to historical conditions based on the pre-dam construction sketch that suggested that the island downstream from the dam was in place prior to dam construction. Thus, the channel will divide into two channels around the island with the main channel to the north, or river right side of the channel. Channel dimensions for the two channels are shown in Appendix K, Figures K-4 and K-5. A second grade control structure is proposed to provide grade control and split the channels at the upstream end of the island (station 45+00, Sheet I-1). Alternative grade control structures will be evaluated in the Phase 3 design. Between the two proposed grade control strucures, the spillway will be removed to a depth approximately 5 ft below the predicted maximum pool depth (or bedrock if encountered before the maximum depth is reached) to provide a margin of safety for additional scour that will occur during flood events. The large existing scour pool downstream from the spillway will fill naturally with bedload.

The powerhouse area and the large existing pool downstream will be filled and graded with material from upstream of the divider block to form a sloping floodprone area blended into the existing ground. Both channels will be stabilized with rock structures and two weirs are proposed to protect the railroad piers and improve hydraulics and sediment transport through the bridge section. Actual channel construction will end just downstream from the island where the two channels converge. If determined necessary for grade control in the Phase 3 design, another grade control structure will be constructed at station 30+00, which is approximately 200 ft to 300 ft downstream from the split channel convergence. From this point downstream, the existing channel appears to be in equilibrium and functioning well. At this point, the river transitions into a stable F3 stream type. No other work is proposed downstream from station 30+00.

Reach CFR1 would have a mean gradient of 0.0031ft/ft. The minimum flood prone width for this channel is about 600 ft at the upstream end narrowing to about 250 ft by station 29+00.

Upstream from the dam site, scour analyses (Envirocon, 2004b) predicted that the channel will scour the finer deposited sediments to native alluvium, near the proposed mean bed elevation. Channel shaping and structure placement in this reach will be completed during the Phase 3 design, but actual channel placement must wait until after stage 3 drawdown (see Section 4.5 for project timeline). The channel upstream from the dam site to the confluence with the BFR may need to be reshaped as structures are placed. Since all channel features upstream from the dam site will not have been subjected to the normal shear stresses that occur during normal runoff events, grade control and bank stabilization structures would need to be constructed at the proposed frequency to prevent channel incision and bank erosion until the bed surface armoring becomes re-established and riparian vegetation matures. These structures would be designed to allow fish passage upstream and downstream at most flow conditions present when the fish are conditioned to move. Also, boating opportunities would be enhanced with any proposed structures. Grade control structures constructed with large rock are appropriate in this geomorphic setting with the south bank encountering a bedrock outcrop.

4.4.2 CFR2 Proposed Treatments

Reach CFR2 will be constructed as a meandering gravel bed channel (C4 stream type) in the upper half of the reach, transitioning into moderately confined, straighter gravel bed channel (B3c stream type) for the lower two-thirds of the reach (Sheet I-2). Floodplain widths would also transition from a width of 1,000 ft at the Duck Bridge grade to approximately 300 ft near the confluence. One of the objectives of both the RA and RP is to balance channel excavation and fill volumes within the restoration project area. Terraces in CFR2 will be constructed to use excess material that is excavated in the reach. The first terrace will be a narrow low terrace about 2 ft higher than the floodplain. A second higher terrace will slope to the existing grade remaining after contaminated sediment removal. The terraces serve the following functions.

- Gradually narrow the floodplain width consistent with the design channel dimensions to transition from a meandering channel (C4 stream type) to a moderately confined channel (B3c stream type).
- Provide additional protection to the SAAIII-b sediments that will remain to the south of the proposed CFR channel alignment.
- Provide additional protection to the Interstate 90 fill slopes to the north of the proposed CFR channel alignment.
- Balance the final cut and fill quantities after sediment removal and floodplain channel and re-grading of the existing sediments has been completed.

The final elevations of the second terrace will be variable and dependent on the final cut and fill quantities determined after contaminated sediment removal. However, the final elevation of the second terrace on the south side, along the SAA IIIb sediments, will be higher than the 100-year flood elevation.

Wetland depressions consistent with the valley morphology were designed to optimize the wetland credits for the area. These wetlands are designed to mimic abandoned river oxbows and are carved into the floodplain and terraces (Appendix I-2 plan view and Appendix K-7 and K-8, cross-sections). However, floodplain stability is of primary concern in the short-term until vegetation can stabilize the area and thus, the wetland depressions are discontinuous in a down-valley direction. The wetlands are designed to allow flood water to back up into the wetland, but not allow frequent floods to access the depressions from upstream. This concept will minimize the potential for flood flows through the wetlands to capture the wetland channels. The wetland depths are variable between 1 ft and 3 ft in elevation below the bankfull floodplain elevation adjacent to the wetland. In most cases, slopes are gentle into and out of the deepest point of the wetland, which occurs around the outside of the depression. This concept allows for the maximum vegetative diversity relative to the duration and elevation of groundwater. For more information on wetland design and revegetation plans, refer to Appendix G.

SAA II and III sediments with low contaminant concentrations may be graded to fill some of the volume created by the removal of the SAA I sediments. The SAA II sediments may be suitable for building floodplains and terraces. Also, since the Duck Bridge grade on the south side creates a constriction on the floodplain during major floods, the fill will be excavated down to the floodplain elevation and used as fill for the low areas. Removing the Duck Bridge fill will allow a smooth transition from a wider floodplain to a narrower floodplain that will eliminate the rapid constriction that occurs during major floods.

The SAA III-b sediments that currently have relatively high contaminant concentrations would be slightly re-graded to provide drainage, and will then be revegetated in place (Envirocon, 2004a). This work will occur at the transition point between the B3c and C4 stream types. The floodplain narrows significantly at this point. The RA proposes to stabilize the toe of this fill then backfill the toe to the specifications of the grading plan. SAA III-b would remain higher in elevation than the predicted 500-year flood level and would be isolated from flooding by deep fills and gentle, revegetated slopes. Sheets K-7 and K-8 in Appendix K illustrate the conceptual grading in this reach.

The CFR2 channel will be excavated into the pre-dam alluvium surface, which is assumed to be adequate for general bed material. Sediment core information was collected by the Settling Defendants in Remediation Project Area over several years. Coring samples were collected in CFR1, CFR2 and BFR1 to delineate the substrate stratifications and levels of contamination. Coring data were also used to establish the elevation and location of pre-dam alluvium. That information was used to validate the proposed longitudinal profile of the proposed channel through CFR1 and CFR2. Most of the proposed channel would be excavated into this pre-dam alluvium. Unfortunately, the size distribution of this alluvium is limited to a few samples due the method used for collecting the samples. However, the assumption was made that if the alluvium were deposited by the natural channel regime before the dam were in place; it should be suitable as a basis for the channel bed. The existing information will be used in the Phase 3 design to assess channel stability. The exact composition of the alluvium will be determined during the sediment excavation phase of Remediation and final designs will be modified to account for the final sediment distribution. There may be a need to supplement the native

alluvium with screened coarse bed material obtained during construction to further stabilize the riffle segments if necessary.

Floodplain gradient would range from about 0.0034 ft/ft in the upstream C4 valley portion to about 0.0042 ft/ft in the lower B3c valley portion. River gradient would range from about 0.0027 ft/ft in the upstream C4 valley portion to about 0.0036 ft/ft in the lower B3c valley portion. Structures proposed for the downstream B3c portion of this reach are primarily rock grade control and bank stabilization structures similar to those in reach CFR1. The gradient is steeper in this reach than in either the upstream or downstream reaches. Much of the new channel would be constructed on fresh fill that would not have the natural sorting and grade control of a sorted channel bed. To prevent the potential for channel incision and bank erosion, fairly high densities of structures will be required. The grade control structures are intended to create riffle-step morphology. Boating opportunities are also enhanced with the proposed structures. Selection and configuration of structures will be completed in the Phase 3 design.

The C4 portion of the reach would be stabilized primarily with large wood structures such as rootwad/log vane combination structures , engineered log structures and other bioengineered structures shown in Appendix L. These structures are necessary for grade control and bank stabilization until the bed material can become naturally armored and bank vegetation matures. Selection and configuration of structures will be completed in the Phase 3 design.

This plan discusses the concept and criteria for slowly constricting the floodplain as the valley transitions from a laterally unconfined to a confined floodplain system from Reach CFR 3 downstream into Reach CFR 2. The Duck Bridge grade presents an abrupt and severe constriction of the floodplain, particularly after the Milltown Dam is removed. Duck bridge grade is also inconsistent with the goal of restoring a channel and floodplain system consistent with the natural and historical condition. The backwater effect of the Duck Bridge grade during a large flood event would preclude leaving the fill in place as well as the negative aesthetic effects. Consideration has been given to leaving the grade in place and phasing it out over time as floodplain vegetation matures. The costs and future disturbance of phasing out the Grade may outweigh any potential benefits. This option will be considered further in the Phase 3 design.

Although Duck Bridge may offer upstream protection against head cutting and avulsion formation, it also presents an abrupt floodplain constriction and could cause a backwater, upstream deposition and subsequent instability. It is believed that Duck Bridge can be replaced with a structure that offers ample grade control yet does not present the upstream risks. As such, a rock sill is proposed at the upstream end of this reach, approximately where the Duck Bridge fill is to be removed to ensure that the newly constructed floodplain remains secure until the vegetation matures. The proposed sill at the Duck Bridge is proposed as a floodplain grade control to limit potential scour of the floodplain during over-bank flows until the floodplain vegetation can become established. Due to the proposed floodplain slope break and gradual floodplain constriction beginning at Duck Bridge, floodplain grade control is required to resist floodplain erosion caused by flow acceleration generated by the slope break and floodplain constriction.

The details of the proposed sill will be determined in the Phase 3 design, but the concept would be to bury rip-rap rock in a 3'x 3' trench excavated down from the final floodplain surface elevation and extending south until the floodplain tied into the low terrace on the south bank. The proposed sill would be aligned with the Duck Bridge grade. The sill is not intended to prevent an avulsion of the channel, but simply to limit short term floodplain scour, which over time could lead to an avulsion. Other options, such as combination log and rock sills, buried coir logs, brush windrows and other treatments will also be evaluated in the Phase 3 design. A common practice that would be utilized throughout this project area is to locate similar sills wherever a grade control structure is located for a similar purpose (floodplain grade control until vegetation matures). The sill is capped with sod or fill so that it is not visible. This sill could be incorporated into a foundation for a trail or link into proposed bridge abutments. These practices have been used successfully on similar projects.

4.4.3 CFR3 Proposed Treatments

The recommended condition for CFR3 will be a C4 stream type. The upper half of CFR3 will be reconstructed to a predominantly single thread C4 channel with the existing CFR channels converted to discontinuous wetlands as those channels are partially filled with gravel and soil from the new channel excavation. The channel will be constructed so that the proposed floodplain elevations will match the existing floodplain elevations and established floodplain vegetation. The new channel will have hydraulic and meander geometry appropriate for the geomorphic setting and size of the river. Floodplain gradient will be about 0.0034 ft/ft over the total channel length. Whenever possible, the new channel would be constructed to re-activate abandoned oxbows and meanders that appear on the 1937 aerial photographs, the earliest available photographs (See Figures I-5 and I-6 in Appendix I).

To maintain a consistent grade, the lower half of the CFR3 floodplain will be excavated into existing ground. The upstream limit of the floodplain construction in the RP is between Stations 135+00 to 142+00 in the river stationing (Appendix Sheet I-3). This upstream limit is the point at which the floodplain grade "daylights" out at the existing surfaces as shown on sheet J-2, which occurs at Station 120+00 to 125+00 on the valley stationing. At the downstream end of the reach, the floodplain elevation will be excavated into existing ground approximately 7 ft to maintain a relatively consistent floodplain gradient through the reach. The floodplain gradient would remain consistent throughout Reach CFR3. The width of the floodplain would gradually be reduced from greater than 2,000 ft to about 1,000 ft at the downstream end of the reach. The narrowing of the floodplain will continue downstream into reach CFR2 to allow a moderate floodplain transition during large flood events.

The transition to a more confined floodplain would be similar to historical conditions and will also greatly reduce the amount of fill required in CFR2 by lowering the entrance elevation into the reach. Initial estimates indicate that the earthwork will balance in the upstream portion of this reach, but the lower portion will result in an excess of about 200,000 cubic yards. It is proposed that excess excavated material be used to fill the floodplains in CFR2. Material with contaminant concentrations exceeding the desired contamination levels will be handled to meet the objectives. Whenever possible, desireable existing vegetation will be salvaged and transplanted to the new floodplain elevation.

Four potential channel alignments were evaluated during the Phase 2 process for Reach CFR 3. Of those alternatives, two potential alignments were determined to be the most preferred by the design team and peer reviewers. Both fit within the selected range of design dimensions as shown in Sheet I-6 in Appendix I. Since each alignment has specific construction requirements and different effects on landowners, the final alignment will be determined during the Phase 3 design. Lengths and gradients of the two options do not vary significantly. The Team has concluded that Alternative Alignment D is the preferred alignment, which uses the existing channel system. Alignment C will be carried forward as the alternative alignment. Both alignments will undergo a stability assessment as well as review by the involved landowners.

If Alternative D remains as the preferred alignment, minimal work will be done upstream from the floodplain construction limit. However, the channel and floodplain in the reach between 140+00 and 160+00 (Sheet I-3) need to be re-shaped and stabilized with similar structures to connect the downstream reach with the more stable reference reach. The existing channel in this area is braided and relatively unstable.

Although new channel construction will require bank stabilization and grade control until the vegetation can mature, identification of individual structures and treatments in the Reach will occur in Phase 3. Bank stabilization is necessary not only for stable function of the designed channel, but also to minimize erosion of contaminated sediments left in-place. Most of the proposed grade control and bank stabilization objectives will be accomplished with structures constructed predominantly of wood, such as rootwad/log vane combinations, log/rock J hook vanes, engineered log jams and other bioengineered structures shown in Appendix L. Certain grade control objectives could be accomplished with armored pool tail out structures composed of the largest rock found in the existing bed. Structure spacing will be calculated based on structure size, gradient, and stream meander geometry. The grade control structures are designed to match the pool-to-pool spacing common in C4 channels. These structures are designed to function naturally in this geomorphic setting and match the natural stream aesthetics. Fish passage and habitat enhancement are also designed into these structures.

The existing wetlands along the southern portion of this reach will not be graded. It is anticipated that these wetlands and old channels will remain at the low terrace elevation and will be fed by subsurface water from adjacent hill slopes and flood water from the upstream portion of the reach. These wetlands will likely be intermittent with less surface water supplied from the main channel. The existing stream channels will be filled partially, leaving sections of unfilled channel that will be converted to shallow wetlands. It is anticipated that these wetlands will receive water during flood events and when the water table is elevated. To minimize the potential for colonization by undesirable non-native fish species, these wetlands will remain disconnected from the main channel during baseflow conditions.

The current level of design precludes refined detail on the floodplain of CFR3. At this time, many factors are in draft stage, including preferred alignment, proposed floodplain grade, etc. Because of the uncertainty, a highly detailed floodplain and terrace surface was not developed. In CFR 2, much more time was spent on the grading plan and the floodplain/terrace/wetland depressions were highly detailed because the design is much further along in this reach.

Mapping of terrace feature elevations and inundation frequencies will be completed in Phase 3. Due to the extent of proposed excavation in Milltown Reservoir, reach CFR2 is the only reach for which the inundation frequency of terrace features can be designed. Criteria for this effort will rely on recommendations for terrace plant species and subsequent rooting depths from the vegetation assessment; and floodplain width recommendations from the channel stability analysis. Since existing channel and floodplain features will remain at the same elevation in other reaches, terrace features will interact with flood events in a manner consistent with existing conditions.

The concept for the floodplain/terrace/wetland surface for CFR 3 is similar to that for CFR 2 (Sheet I-2). A low terrace would be incorporated that would be inundated at about the 10 to 25 year return interval flood, but have semi-connected wetlands within the floodprone area. In general terms, for the portion of Reach 3 where the floodplain will be excavated and inset (Figure I-3, from Station 140+00 to 100+00 +/-), the existing floodplain will transition from a floodplain to a low terrace to a high terrace proceeding in a downstream direction. The concept discussed herein focuses on providing a gradual transition in floodplain or floodprone width from over 2000 feet to less than 1000 feet over a 3000 foot linear distance to minimize backwater effect that would affect sediment transport during large floods. A detailed floodplain transition and terrace surface will be developed in Phase 3 after the proposed alignment and grade are finalized.

The downstream portion of CFR3 will need to be completed before CFR2 finish work and structures are initiated. Water will most likely be diverted into the north branch of the existing CFR channel system during construction of the inset floodplain. At that point, the river will continue to flow through the bypass channel constructed during RA. Construction logistics will be finalized in the Phase 3 design.

Subsurface material composition is limited to a few samples. The lack of data in the area upstream from Duck Bridge was recognized as a limiting factor in the design and additional supplemental core data will be collected to determine distribution and contamination of sediments. The supplemental core data will be utilized in the Phase 3 design for CFR3. There may be a need to supplement the native alluvium with screened coarse bed material obtained during construction to further stabilize the riffle segments if necessary.

In addition to reconstructing the CFR3 channel, it will be necessary to construct a new channel for Deer Creek, a small tributary to the CFR on the south side of the CFR near the Duck Bridge. Deer Creek has been identified as an important spawning stream for westslope cutthroat trout by Montana Fish, Wildlife & Parks (P. Saffel, MFWP, personal communication). Since the floodplain for CFR3 will be lowered by up to 7 ft at the confluence point with Deer Creek, near station 94+00 (valley stationing), Deer Creek will need to be reconstructed to provide a stable and productive stream consistent with the geomorphic setting that will match elevation with the CFR at the confluence. The proposed channel is a sinuous, unconfined single thread channel (E4 stream type) that would be approximately 6 ft wide and about 1 ft deep. The new channel will be constructed within the existing wetland swale as shown in Appendix I. Design dimensions, alignment, and details for Deer Creek will be determined in the Phase 3 design.

The proposed plan for reconstructing and connecting Deer Creek with the CFR is conceptual at this time. No hydrology or design elevations have been established at this time because the issue of connecting Deer Creek with the CFR arose late in the Phase 2 process. The Deer Creek culvert and channel downstream from the culvert will be designed to provide fish passage from the Clark Fork River upstream to Deer Creek if deemed appropriate by MFWP. The pure strain westslope cutthroat trout population upstream of the culvert may be deemed critical and MFWP may select to maintain the genetic integrity of the population by limiting fish passage to the upper Deer Creek watershed.

Regardless of the decision on fish passage through the Deer Creek culvert, the concept is to construct a new channel that will be designed to converge with the CFR at an appropriate elevation and location. Grade control structures will be minimized. Based on the preliminary design and elevation information, the elevation of the bottom of the existing swale that currently carries Deer Creek water (also the proposed location for the new channel, Figure I-3, Appendix I) enters the CFR at approximately the correct floodplain elevation. The specific design for the Deer Creek culvert and channel will be addressed in Phase 3.

4.4.4 BFR1 Proposed Treatments

BFR1 will need to incorporate several actions during the entire project construction period including the following considerations.

- Stimson Dam removal and associated channel stabilization.
- Grade stabilization of highway and railroad bridge crossings.
- Three-stage drawdown of the reservoir and the associated scour that will occur during drawdown (refer to Section 4.6.3 for a description of drawdown stages).
- Completion of the portion of BFR1 upstream from the bridges and downstream from Stimson Dam.

Stimson Dam will be removed by other parties early in the construction process during stage 1 drawdown. The bridge grade controls for Interstate 90 will be completed during stage 2 drawdown. The remainder of the channel construction to the upstream terminus will be completed during stage 3 drawdown. The upstream terminus of construction is the Stimson Dam, although some of this reach may not need much work due to the predicted scour. Actual channel construction in the reach upstream from the footbridge to Stimson Dam will be determined during Phase 3 design.

It is recommended that BFR1 be converted from an F4 stream type with backwater conditions to a B3c stream type with step-pool morphology and a narrow, well-vegetated flood prone area similar to upstream reference reaches. Scour of the existing sediment deposits will occur during stage 3 drawdown (Envirocon, 2004b). Scour is expected to occur down to the pre-dam alluvium elevation in the vicinity of the bridges. The resultant bed elevation after scour is predicted to be similar to the mean proposed channel bed elevation. The resulting channel and floodplain will likely need to be reshaped to the design dimensions. This will be accomplished by reshaping the existing bed material, where necessary, and grading a sloping floodplain. It is

likely that earthwork can balance in this reach. The gradient will be consistent throughout the reach at about 0.0025 ft/ft.

BFR1 downstream from the Interstate 90 bridges to the confluence with the CFR will undergo scour during stage 3 drawdown. The scour analysis (Envirocon, 2004b) predicted that scour will occur down to the depth of alluvium, near the proposed mean bed elevation. Channel shaping and structure placement in this reach will be determined during the Phase 3 design. However, channel alignment must wait until after stage 3 drawdown scour. This reach of channel may need to be reshaped as structures are placed. Since all channel features upstream from the dam site will not have been subjected to the normal shear stresses that occur during normal runoff events, grade control and bank stabilization structures would need to be constructed at the proposed frequency to prevent channel down cutting and bank erosion until the natural sorting can take place and the vegetation matures. These structures are designed to allow fish passage upstream and downstream at most flow conditions present when the fish are conditioned to move. Also, river boating opportunities are enhanced with the proposed structures.

Only structures deemed critical for coordinating with RA are addressed in detail in the RP. Such structures are identified to allow for review and comment by the peer review panel. Additional structure details will be finalized in the Phase 3 design. Structures proposed in this reach would provide multiple benefits for various functions including grade control, bank stabilization, fish habitat complexity and river floating. Since this reach is a large river and substantial bedload movement, the structures will be constructed primarily of large rock. Large woody debris and rootwads will be incorporated into most structures for habitat. Refer to Appendix L for descriptions and illustrations of the proposed structures.

It is recommended that two abandoned piers at the old Highway 200 Bridge crossing are removed to improve channel stability. In general, bridge spans are adequate to span the active channel and flood prone area, but the railroad bridge is skewed enough to reduce the effective capacity to convey flood flows. A series of rock weirs may be necessary to split the active channel around the piers while maintaining hydraulic function. Any selected structure needs to maintain grade, reduce bank erosion, provide for fish passage and allow for safe recreational boating. W-weirs (Appendix L) effectively provide all of the these functions, however all options will be addressed in the Phase 3 design. Other channel structures would be similar to those on the CFR1 and CFR2, with rock steps constructed to provide grade control, allow fish passage, and provide boating opportunities.

4.4.5 Selected Floodplain Dimensions

For the lower half of CFR1 and the upper portion of BFR1, the floodplain is determined by the width of the high terraces that confine the floodplain. For the remaining reaches, floodplain dimensions were determined using the reference data from valley morphology reference reaches, other reference reach data, hydraulic modeling results and surveyed pre-dam cross-sections from 1905. The objective for the CFR3, CFR2 and BFR confluence is to slowly transition from a broad unconfined valley and floodplain in CFR3 to a confined and entrenched floodplain at the downstream end of CFR2. The confluence will be slightly wider to accommodate the additional

flood flows, and then transition to the width of the confining terraces downstream from the railroad bridge in CFR1.

4.4.6 Selected Channel Profile and Habitat Unit Slopes

Proposed floodplain gradients are presented in Appendix J. The longitudinal profile was developed with the objective of maintaining appropriate sediment transport, conveyance capacity, and keying the proposed floodplain to existing floodplains and vegetated features in areas that were not directly affected by backwater and deposition from Milltown Dam. Floodplain gradients were kept as constant as possible to minimize potential problems associated with flow acceleration. The proposed gradient is shown as a floodplain gradient at bankfull stage and a consistent bed profile that is parallel to the water surface profile. The bed gradient is not intended to illustrate pool, riffle, run and glide habitats, but rather to indicate the elevation of the grade control at any point in the profile. More detailed profiles will be developed during Phase 3 design.

4.4.6.1 CFR Profile

For the CFR reaches, the valley gradient is illustrated rather than the stream profile (Appendix J). With the variation in alternative channel alignments and a range of associated sinuosity values, the longitudinal profile could vary. For this reason, the valley profile is illustrated with the understanding that the channel gradient can be calculated by dividing the total change in elevation by the total channel length. For CFR3, the floodplain elevation (bankfull stage) in the upstream portion of the reach was determined by the topographic survey. The field determined floodplain elevation was located and surveyed in the existing channel systems. This floodplain elevation was also validated using the cross-sections that were derived from the topographic surface developed from both the land based surveys and aerial photogrammetry. A best-fit line was developed along the valley profile for the floodplain elevation and plotted on the CFR profile.

At approximately station 120+00 on the valley profile, the floodplain of CFR3 flattens corresponding to the backwater elevation of Milltown Dam during floods. The 1908 flood was calculated to have a maximum elevation of 3265.5 feet (Envirocon, 2005), which occurs at about station 125+00 feet on the profile. In other words, downstream from station 125+00, the 1908 flood caused contaminated sediment deposition and backwater conditions. It is possible that the deposition from the 1908 flood also caused head ward aggradation of the channel due to a flattened gradient at that point. However, the channel and floodplain system seem to have adjusted over the last century to a relatively consistent floodplain gradient upstream from station 125+00. The mean floodplain valley gradient for CFR3 upstream from station 120+00 is about 0.0032 ft/ft. Extending this trend line downstream to Duck Bridge would result in a floodplain elevation of about 3255.5 feet, which is about six to seven feet below the existing floodplain elevation. To maintain a consistent floodplain gradient for CFR3, the floodplain for the lower portion of CFR3 would need to be lowered 7 ft at station 94+00 and day-lighting at station 120+00.

During reservoir drawdown in 2004, three submerged tree stumps were observed at station 120+00. These stumps were anchored into the historical channel feature and have been preserved by being submerged in water since the dam was built. The stumps are about 4 ft below the proposed floodplain trend line, suggesting a lower historical floodplain elevation relative to the existing condition.

The same process was used for CFR1 downstream from Milltown Dam, where the bankfull stage indicators have stabilized since construction of the dam. Again, a best-fit line was developed along the valley gradient and extended upstream to the confluence with the BFR at valley station 56+00. The floodplain indicators were consistent with the best-fit line for a mean gradient of 0.0031 ft/ft, which is nearly the same as CFR3 upstream from station 125+00. However, if the CFR1 floodplain gradient trend line was extended upstream to station 120+00, it would fall about 4 ft below the CFR3 trend line at that location. Coincidentally, the CFR1 trend line elevation at station 120+00 lines up closely with the location of the tree stumps previously identified at station 120+00.

The CFR2 floodplain gradient was developed by connecting the CFR3 trend line at Duck Bridge to the BFR1 trend line at the confluence, a distance of 3,800 ft. The resultant line gradient is equal to 0.0043 ft/ft and results in an increase of the gradient at Duck Bridge.

Using the proposed floodplain elevation trend lines, the bed elevation was plotted on the profile based on the maximum riffle depth, which is the mean bed grade line. This bed grade line is not intended to show the actual bed construction with run, pool and glide habitats, but to indicate the mean bed grade elevation at any point in the valley profile. Comparing the CFR2 bed profile to the pre-dam alluvium sampling (Envirocon, 2004b), CFR2 bed elevations are lower than the pre-dam alluvium surface. As such, the CFR2 channel would be excavated into the alluvium, meeting desired objectives. A portion of CFR2 where the channel would not be at the pre-dam alluvium elevation occurs between station 80+00 and 94+00. In this section, the pre-dam alluvium is deeper than the mean bed elevation based on the subsurface sampling. The sampling density was less in this area and the actual alluvium depth will need to be further evaluated. Also, minimal sub-surface sampling has been completed in the area upstream from Duck Bridge to develop a pre-dam alluvium layer. However, the sediment coring, the shift in trend lines between CFR1 and CFR3, and the elevation of the tree stumps indicate that the proposed floodplain elevation at Duck Bridge may be about 4 ft higher than historical conditions.

For the RP, it was assumed that it would be less desirable to reduce the elevation at Duck Bridge by another four feet. This would result in significant additional costs to excavate the entire floodplain for an additional 5,000 ft upstream. It was assumed that the change in gradient at Duck Bridge could be accommodated by some additional grade control constructed throughout the CFR2 reach. However, it may require importing coarse material for constructing the streambed in the upper 1,600 ft of CFR2. These assumptions will be evaluated by the peer review group and additional data will be collected during Phase 3 designs. It was also deemed more important to be consistent with the downstream tie in points.

4.4.6.2 BFR1 Profile

Similar surface and subsurface data were available for developing the BFR1 profile. Since this reach is currently under backwater conditions, there is no survey information available pertaining to the floodplain elevations. The confluence elevation was determined by the CFR1 profile. The upstream bed elevation was estimated by the alluvium layer that was determined by Envirocon (SOW 2005) and CH2MHill (2004), assuming post-scour and with Stimson Dam removed. A straight best-fit line was estimated through BFR1 and extended upstream to about station 80+00, which is located upstream from Stimson Dam. This grade line was assumed to be the mean thalweg elevation. The maximum riffle depth was added to the thalweg elevation to determine the floodplain elevation. The resulting floodplain grade line has a consistent gradient of 0.0025 ft/ft. Again, the mean bed elevation does not include the habitat features that will be detailed in the Phase 3 design. The proposed grade line fits the predicted scour and alluvium surface line fairly well. The proposed mean bed elevation is close to the existing bed elevations at all bridges except the Burlington Northern-Santa Fe railroad bridge. The existing bed at the railroad bridge appears to be predominantly finer sediment deposition. More information regarding the work around Stimson Dam will be necessary to finalize the upstream portion of the longitudinal profile. It is anticipated that additional data and analyses will be completed by all parties prior to completing the design on the proposed bridge grade control structures. Removal of Stimson Dam and the scour related to stage 1 and stage 2 Milltown reservoir drawdown, will be monitored to refine the predictions. The upstream portion of the profile will be determined during the Phase 3 design.

4.4.7 Meander Geometry and Channel Alignment Alternatives

The channel planform geometry is a function of the bankfull discharge and the bankfull design width. The most probable channel patterns for the restoration project area reaches were determined from empirical models developed by Leopold et al. (1964), Williams (1986), Rosgen (1996), and a reference reach database as described in Appendix B.

The empirical models and analysis provided a range of values for channel pattern attributes rather than specific values for channel pattern. The channel patterns and locations may be adjusted to account for the final condition of the valley bottom following RA. Where feasible, the new channel will incorporate established vegetation to provide bank stability and habitat. Available data sources used to develop the channel alignments, longitudinal profiles and cross sections included the complete topographic basemap developed by RDG, additional surface and subsurface elevation models developed by Envirocon, historical channel cross-section data from the Milltown Dam area circa 1905, aerial photograph series, and other data summarized in Appendices B and D.

In BFR1 and CFR1 the channel characteristics were dictated by existing conditions and infrastructure constraints. There was limited valley width available for aligning these channel segments. The CFR2 alignment was developed from design criteria, but was also subject to certain construction constraints. The CFR2 alignment has not changed appreciably from the DCRP proposed alignment. Due to the wider valley bottom, four different potential channel alignments are possible in CFR3. All potential alignments fit within the selected range of design

dimensions as shown on Sheet I-6 in Appendix I. Of the four potential alignments, two were selected for additional evaluation in the Phase 3 process. After further discussion by the design team, Trustees and peer group, Alignment D is now the preferred option. Alignment C will be continued and evaluated in Phase 3 along with any other potential alignment locations based on landowner objectives. Since each alignment has specific construction requirements and different effects on landowners, the final alignment will be determined during the Phase 3 design. Lengths and gradients of the four options do not vary significantly. Alignment C was selected to evaluate hydraulics, channel stability, and sediment transport for CFR3.

4.5 REACH SPECIFIC REVEGETATION RECOMMENDATIONS

4.5.1 CFR1 Revegetation Treatments

The restoration strategy in Reach CFR1 includes changing the elevation of the island in the middle of Clark Fork River channel, narrowing the channel, and creating a bankfull bench along the channel. The revegetation strategy includes salvaging the native shrub vegetation from the island prior to re-grading (Table 4-4). New areas of floodplain will be created on the downstream side of the island and on the north side of the Clark Fork River downstream of the confluence of the Clark Fork and Blackfoot rivers. The substrate in the new floodplain areas will consist of sand in most areas and a sand-loam mixture in lower elevation depressions created during final grading. The floodplain seed mix and planting mix will be used in these areas. Approximately 30 percent of the floodplain will be mulched with mulch treatments restricted to areas not prone to annual flooding. A streambank depositional area will be created on the north bank of the Clark Fork River at the confluence. The substrate will consist of gravel and cobbles with floodplain elevation grading combined with windrow areas. Depositional areas will not be planted and will be seeded using the ephemeral seed mix strategy. Other streambank areas will have substrate consisting of a sand and loam mixture on a bankfull bench. Streambanks may also have bioengineering structures consisting soil lifts or large woody debris. The streambank seed bank and planting mix will be used in these areas. Large wood debris will be placed in both the floodplain and steambank depositional areas. Large wood will not be used on the surfaces in other streambank areas.

Table 4-4. The revegetation strategy for Reach CFR1.

Feature	Area (acres)	Salvage	Substrate	Seed	Grading	Mulch	Plants	Bio-engineering	LWD
Floodplain	6.1	Yes	S/L	FP	FP/D	30%	Flood-plain Mix	No	Yes
Streambank Depositional	5.7	No	G/C	Eph	FP/W	No	No	No	Yes
Streambank Other	5.8	No	S/L	SB/ Eph	BF Bench	No	Stream-bank Mix	Soil Lifts or Woody Debris	No

4.5.2 CFR2 Revegetation Treatments

The restoration strategy in CFR 2 includes removing sediment from the channel and reservoir to create a new channel elevation and narrower channel (Table 4-5). Re-grading work will begin

long enough before revegetation work so that salvaging and preserving existing plant material may not be feasible. The revegetation strategy will result in new areas of floodplain, streambank including depositional areas, wetland, and upland in Reach CFR2. Floodplain consists of areas in the active floodplain outside of the streambanks. Final grading will create a floodplain elevation with some depressions. A sandy substrate will be used to create the floodplain and a loam mixture will be used in the depressions. Approximately 30 percent of the floodplain will be mulched in non-floodprone areas. The floodplain seed mix and plant mix will be used in these areas.

Depositional streambank areas will be graded up to the floodplain elevation using gravel and cobble substrate and will also contain windrow areas. Depositional areas will not be mulched or planted and will be seeded using the ephemeral seed mix strategy. Other streambanks will be graded to the bankfull bench elevation and the substrate will consist of sand. Bioengineering structures consisting of soil lifts or woody debris may be used along stretches of these streambanks. Other streambank areas will be planted and seeded using the streambank seed and plant mixes. Wetlands will be created in both the upland and floodplain areas of CFR 2. Wetlands will be graded to depressions with loamy soils. Prevegetated coir mats may be used around the edges of some of the wetland and the wetlands will be seeded and planted using the wetland seed and planting mixes. Uplands will be created outside of the active floodplain, adjacent to the floodplain. These areas will be graded to the upland elevation and consist of a sand to loam substrate. Approximately 30 percent of the upland area will be mulched. Uplands will be seeded and planted using the upland seed and plant mixes. Large wood will be placed on the surface in the floodplain, wetlands and uplands to add roughness and create microsites.

Table 4-5. The revegetation strategy for Reach CFR2.

Feature	Area (acres)	Salvage	Substrate	Seed	Grading	Mulch	Plants	Bio-engineering	LWD
Floodplain	32.3	No	S/L	FP/ Eph	FP/D	30%	Flood-plain Mix	No	Yes
Streambank Depositional	20.0	No	G/C	Eph	FP/W	No	No	No	Yes
Streambank Other	5.0	No	S	SB	BF Bench	No	Stream-bank Mix	Soil Lifts or Woody Debris	No
Wetland	13.3	No	L	Wet-land Mix	D	40%	Wetland Mix	Pre-Vegetated Coir Mats 10%	Yes
Upland	47.8	No	S/L	Upland Mix	Upland/ D	30%	Upland Mix	No	Yes

4.5.3 CFR3 Revegetation Treatments

The restoration strategy in the downstream portion of Reach CFR3 includes removing sediment from the existing channel and floodplain to create a new channel elevation and narrower channel. The restoration strategy in the upstream portion of CFR3 is to create a narrower, more sinuous channel and a narrower active floodplain. Approximately eight acres of new floodplain will be created in the downstream portion of the reach (Table 4-6). This area will be graded to the

floodplain elevation with some depression. Substrate in the floodplain will consist of sand with loam in the depressions. Non-floodprone areas of the newly created floodplain will be mulched. The floodplain seed and plant mix will be used in the newly created areas of floodplain only. New streambanks will be created throughout the reach. Depositional streambanks will be graded up to the floodplain elevation and consist of gravel and cobble substrate. The ephemeral seed mix and strategy will be used in these areas. Other streambank areas will be graded to the bankfull bench elevation and have a sandy substrate. Bioengineering structures consisting of soil lifts or woody debris may be used along stretches of the non-depositional streambanks. Other streambank areas will be seeded and planted using the streambank seed and plant mixes. Wetlands will be created in the newly created areas of floodplain and upland. Abandoned channel features in the upstream portion of the reach will also be converted to wetlands. Wetland may be either be graded or filled to the depression elevation. A loam substrate will be applied in these areas and the wetland seed and plant mixes will be used. Pre-vegetated coir mats may be used on the outside edges of the wetlands. Uplands will be created outside of the active floodplain in the downstream portion of the reach where sediments will be removed. Uplands will be graded to the upland elevation and will consist of a sand or loam substrate. The upland seed and planting mixes will be used in these areas. Large wood will be placed on the surface in the floodplain, depositional streambanks, wetlands, and uplands to add roughness and create microsites.

Table 4-6. The revegetation strategy for Reach CFR3.

Feature	Area (acres)	Salvage	Substrate	Seed	Grading	Mulch	Plants	Bio-engineering	LWD
Floodplain (8 acres will be bare ground)	160.0	Yes (8 ac)	S/L (8 ac)	FP (8 ac)	FP/D (8 ac)	30% (8 ac)	Floodplain Mix (8 ac)	No	Yes
Streambank Depositional	26.2	Yes	G/C	Eph	FP/W	No	No	No	Yes
Streambank Other	19.0	Yes	S/L	SB/Eph	BF Bench	No	Stream-bank Mix	Soil Lifts or Woody Debris	No
Wetland	38.0	No	L	Wetland Mix	D	40%	Wetland Mix	Pre-Vegetated Coir Mats 10%	Yes
Upland	33.1	Yes	S/L	Upland Mix	Upland/ D	30%	Upland Mix	No	Yes

4.5.4 BFR1 Revegetation Treatments

The restoration strategy in Reach BFR1 will convert the existing open water reservoir to narrower moderately-entrenched channels. The reconstructed floodplain in Reach BFR1 will consist of a narrow floodplain surface adjacent to the channel. Existing native vegetation along the currently banks will be salvaged and moved to the newly created bank edge. New streambanks will be created at a bankfull bench to floodplain elevation throughout the reach but are considered part of the floodplain in the reach. New substrate throughout the reach will consist of sand, gravel and cobbles. The floodplain seed and plant mix will be used throughout the reach without any mulch (Table 4-7). No bioengineering structures are proposed. Large wood will be placed on the floodplain surface to add roughness and create microsites.

Table 4-7. The revegetation strategy for Reach BFR1.

Feature	Area (acres)	Salvage	Substrate	Seed	Grading	Mulch	Plants	Bio-engineering	LWD
Floodplain	14.3	Yes	S/G/C	FP/Eph	BF Bench/ FP	No	Flood-plain Mix	No	No

4.6 PROJECT TIMELINE AND CONSTRUCTION SEQUENCING

The project timeline and sequencing has changed substantially from the CRP due to major changes in Remediation Action (RA) design. The entire construction time frame for RA has been reduced to about four years and the scope of the restoration project area has been reduced from six reaches to four reaches (Table 4-8).

The timing of most work will ultimately be governed by the drawdown stages and RA schedule. The Scope of Work (SOW) document prepared by Envirocon (Envirocon 2004a) contains a detailed discussion of the drawdown stages and associated RA work that will occur during those stages.

4.6.1 Reservoir Drawdown and Dam Removal

In summary, reservoir drawdown and dam removal are planned to occur in three stages. All stages are timed with the spring runoff period to minimize construction costs and sediment impacts as discussed in the Envirocon SOW.

4.6.1.1 Stage 1

The Radial Gate will be opened to allow the reservoir to drop about 10 feet in elevation. During this time, the CFR will remain in its channel while the bypass channel is being constructed between Duck Bridge and the confluence with the BFR (reach CFR2). Stimson Dam is also removed before or during this stage, which lasts about 1 year.

4.6.1.2 Stage 2

Water from the CFR will be diverted into the bypass channel. The Powerhouse turbine inlets are converted to low level outlets allowing an additional 5 to 6 feet of drawdown (15 to 16 feet total drawdown). During this time period, the spillway will be removed and the new CFR1 channel constructed through the spillway reach. This stage occurs over about 6-7 months between spring runoff periods.

4.6.1.3 Stage 3

Water will be diverted into the new CFR1 channel at the old spillway location allowing the reservoir to be drawn down an additional 12-13 feet for a total drawdown of approximately 27 ft to 29 ft. During the first part of stage 3, stage 3A, the powerhouse, radial gates and other structures associated with the dam will be removed. During the second part of this stage, stage 3B, sediment will be excavated from SAA I.

4.6.2 Coordination of Restoration Actions with Remedial Actions

Since the drawdown stages will ultimately determine the timing for restoration actions, the restoration actions have been grouped and discussed by drawdown stage. When developing the restoration timeline, the following items were identified as the most critical activities for restoration work to accomplish in order to coordinate with RA.

1. The State must coordinate with RA to ensure that reaches upstream and downstream of the restoration project area are prepared to accommodate the bypass diversions.

2. Certain restoration actions may need to be accomplished prior to the pertinent drawdown stage in order to protect existing infrastructure. An example of this is the grade control and bridges protection structures on BFR1.

3. To minimize sedimentation and disturbance, the State should be prepared to take advantage of the required sediment control, river diversions and de-watering infrastructure required for RA. Such an example would be to take advantage of dry working conditions offered by coffer dams constructed during RA.

4. To reduce risk of damage and reduce the cost of restoration, the State must be prepared to work within a fixed time period to complete certain restoration actions following RA sediment removal.

4.6.3 Implementation Schedule

A proposed implementation schedule is presented in Table 4-8. The schedule includes tasks related to restoration design, construction, revegetation and monitoring for the four project reaches. The implementation schedule has been integrated with the RA construction and reservoir drawdown stages as shown on the top line of the schedule. The proposed implementation schedule displays the approximate time frames for the drawdown stages and the subsequent restoration action associated with each stage. Following approval of the Envirocon SOW, a calendar will be incorporated into the implementation schedule

4.6.3.1 Stage 1 Restoration Actions (Year 1 and 2)

No restoration construction will take place during stage 1. Stage 1 will draw the reservoir down to a similar level as recent draw downs. During stage 1, one runoff event will occur. Cooperating parties will remove the Stimson Dam before runoff occurs.

Depending on the schedule, it may be necessary to collect supplemental design data identified in the peer review process. Phase 3 design should be completed at least six months prior to stage 2, and preferably one year before stage 2. At a minimum, floodplain profiles should be finalized. Grade control structures on CFR1 near the dam and the BFR bridge sites should be completed at least six months prior to stage 2. Minimal time will be available to organize materials, logistics and complete the permitting process. Phase 3 designs may be completed for CFR2 and CFR3 over a slightly longer time period, but at least one year before initiation of Stage 3B so that

Envirocon can prepare a final grading plan for SAA I. If possible, revegetation treatments can be implemented in areas that will remain unaffected by other construction activities. Possible treatments include weed treatments, plant salvage and planting.

4.6.3.2 Stage 2 Restoration Actions (Year 2 and 3)

During Stage 2, the reservoir will be drawn down to the minimum pool elevation possible without removing the spillway and dam. The reservoir will be drawn down approximately 15 to 16 feet from full pool. Stage 2 will begin in the fall following the stage 1 runoff event, and continue through the following spring. Stage 2 actions must be completed before the next runoff season to protect the infrastructure constructed during stage 1. The duration of stage 2 will be about six to seven months. To take advantage of drawdown and the RA coffer dam installed upstream from Milltown Dam to divert water through the radial gate, several restoration construction activities will take place during this short time period. The grade control structures for CFR 1 channel will be completed along with channel construction from approximately 200 feet upstream of the dam to approximately 700 feet downstream of the dam during dry conditions. This construction will entail constructing grade control weirs in the CFR1 along with a coffer dam downstream of the dam to separate the new floodplain from the active channel. Also during this time period, the side channel on the river left side downstream from the dam will be reshaped according the final plan.

Other restoration activities that must be completed during stage 2 are the grade control structures on BFR1, if deemed necessary during the Phase 3 design. To protect the bridge piers, structures must be installed before stage 3 drawdown is initiated. After the structures are placed in CFR1 and BFR1, the coffer dam will be removed and the CFR will flow through the new CFR1 channel at the dam site. If possible, revegetation treatments can be implemented in areas that will remain unaffected by other construction activities. Possible treatments include weed treatments, plant salvage and planting.

4.6.3.3 Stage 3 Restoration Actions (Year 3)

Stage 3A begins before the second spring runoff and continues until the powerhouse, radial gate and associated structures are removed. One runoff event will occur during stage 3A, which will cause some scour upstream from the dam in CFR1 and the lower section of BFR1. Channel scour is planned and covered in detail in the Envirocon scour reports. The resultant water levels will be approximately at the final proposed water surface elevations in the lower reaches of the project.

Immediately after the runoff event has concluded and water levels drop to low flow conditions, the water can be diverted into the left side channel of the CFR1 downstream from the dam. This will allow the CFR1 channel and floodplain downstream from the dam to be completed in dry conditions. Also during this time period, the BFR1 channel upstream from the bridges to the terminus of the reach may be completed.

If necessary, the construction of CFR1 downstream from the dam and BFR1 upstream from the bridges could be completed later in the planning process, in year 5 or 6. This delay may be

necessary if designs, permits or other considerations preclude completing the work during year 3. However, the water quality impacts associated with delays could prolong the period of sedimentation.

Revegetation efforts will be completed in phases before, during and after construction. Any equipment based revegetation will closely follow the final construction of any segment of river. Hand based planting will occur following construction and will extend for several years after construction.

4.6.3.4 Stage 3B and 3C Restoration Actions (Year 4 and 5)

While Envirocon is removing sediment from SAA1 (CFR2), restoration actions will focus on the upper CFR reaches. Ideally, the upper half of CFR3 will be completed in Year 3 and 4. This will concentrate all water into a single channel, which can be diverted in the northernmost existing channel. This diversion will allow the excavation and construction of the lower half of CFR3, which requires lowering the floodplain by up to seven feet. The timing for the upper half of CFR3 is not as critical as the lower half of CFR3, however, because the lower half will need to be closely tied to the final grading of CFR2 by Envirocon. There will be an excess of approximately 200,000 cubic yards of material generated from excavating the floodplain in this reach. The material will be used for general fill and growth medium in CFR2. There is an opportunity to stockpile this material, but the costs would increase each time the fill is moved. The lower half of CFR3 will be coordinated with the final grading of CFR2.

The floodplain elevation of the upper half of CFR3 will not be changed appreciably, so construction of this reach could wait until year 5. However, any delays in construction could increase risk of damage to downstream reaches due to runoff events or floods. Planning in advance for this risk would be necessary and could also increase costs.

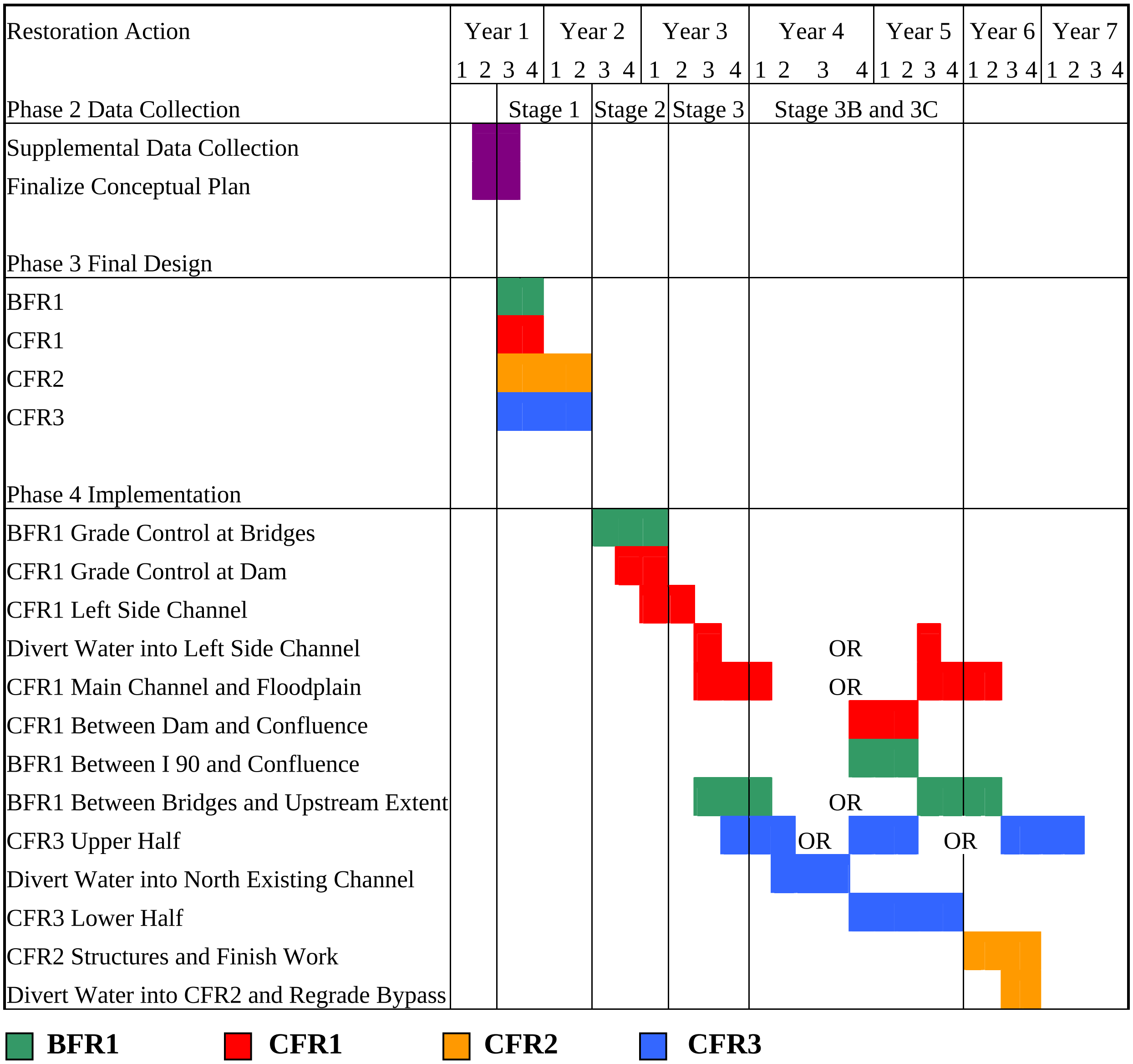
As soon as the lower half of CFR3 and the final grading of the CFR2 channel and floodplain are complete, the structures can be installed. Finish work and revegetation will follow in CFR2. Water would be diverted into the new channels, and the bypass channel would be regraded to final elevations. Revegetation in CFR2 and CFR3 would begin upon completion of final grading and continue for one year.

During year 4 or 5 low flow periods, CFR1 and BFR1 between the dam and Interstate 90 will be completed. The Envirocon scour model predicts that the scour process will scour the channel to alluvium, near proposed bed elevations. However, additional channel shaping, pool excavation and structure placement will need to be completed. This work must be accomplished in wet conditions.

4.6.3.5 Restoration Activities Following Stage 3 (Year 6-9)

As discussed previously, channel work not completed during stage 3 will be completed in year 6 or year 7. Reaches that may fall into this category are CFR1 downstream from the dam and BFR1 upstream from the bridges.

Table 4-8. Restoration schedule for the CFR and BFR.



4.7 MONITORING NEEDS

The proposed EPA remediation plan includes monitoring for groundwater, surface water (quality and quantity) and biological conditions. The CRP introduces several concepts that will also require monitoring. The proposed monitoring for the CRP would be in addition to that monitoring proposed in the EPA remediation plan. It would primarily consist of monitoring the channel conditions, including channel geometry and vegetation success. Monitoring would begin one year after implementation and continue every other year over a period of 10 years. Ultimately, project monitoring would be developed in conjunction with stakeholders and permitting agencies.

To monitor the channel condition, permanent cross sections and profile locations would be established. Cross sections would be located in multiple representative pool, riffle, glide and run habitats. A channel survey, pebble count, and photo point would be completed at each cross-section. Profile stations would be established at channel habitat feature transitions to quantify channel feature changes. Bank pins would also be installed at selected locations within the restoration project area and untreated reaches to compare bank erosion and sediment input rates.

Elevation measurements and photo points would also be completed for each structure. Measuring structure and bed elevations over time would improve the understanding of sediment transport, energy dissipation, and habitat maintenance created by the structures.

Vegetation monitoring would include evaluating treated and untreated reaches for relevant attributes such as vegetation composition and cover, utilization, shrub and tree regeneration, and coarse woody debris. Noting the presence and abundance of noxious vegetation, particularly where weeds have been treated with this project, would be essential to the vegetation monitoring program.

At this time, the proposed monitoring program is still in the planning phase. The preceding recommendations are based on standard monitoring techniques. A monitoring program would be critical for evaluating restoration success. Specific monitoring would be developed during the Phase 3 design and permitting phase of the project.

4.8 MAINTENANCE NEEDS

A maintenance regime would be implemented to address revegetation, structure and channel adjustments that may occur following project construction. The proposed maintenance plan includes assessing the restoration project areas 1, 3, 5, 7, and 10 years after the completion of the projects. The recommended maintenance budget would be one percent of the project cost weighted by the length of the project reach. Maintenance may include reconstructing failed structures, adding additional structures, additional vegetation planting, noxious weed treatments or channel mod